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FOUNDATIONS FOR FARM BUILDINGS

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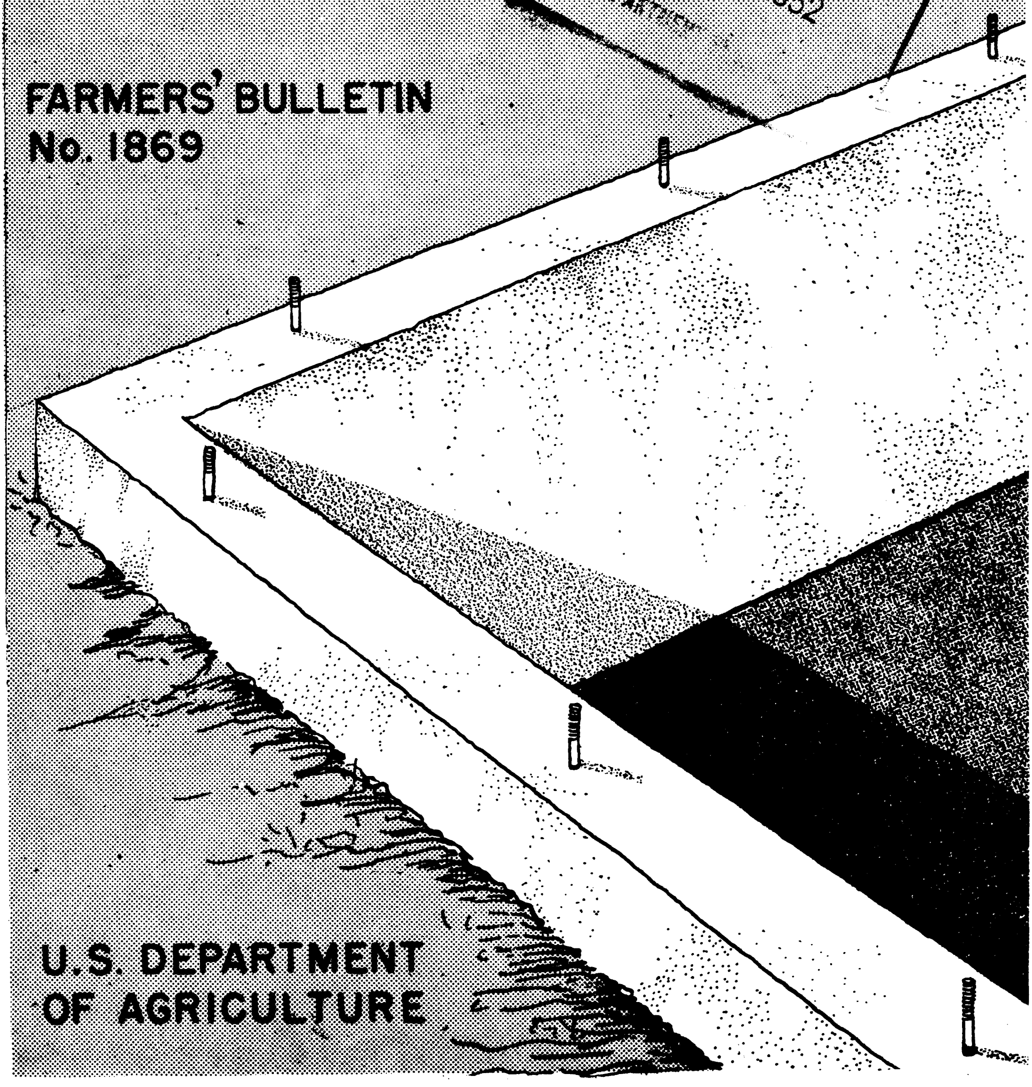

U.S. DEPARTMENT OF AGRICULTURE

THE foundation is the most vital part of a structure. To put a well-built superstructure on a poor foundation is a waste of time and money. A well-constructed foundation of suitable type provides stability, low depreciation, and protection from ground water, termites, rodents, and decay.

To design a good foundation, especially if soil conditions are unfavorable, requires considerable technical knowledge. However, careful workmanship and good judgment in the application of simple but often-neglected principles, will reduce the number of farm-building failures caused directly by faulty foundations.

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FOUNDATIONS FOR FARM BUILDINGS

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Contents

INTRODUCTION

THE FOLLOWING general recommendations point out common errors and are intended to assist farmers to provide suitable foundations for ordinary farm structures except where unusual soil conditions are found.

The foundation of a farm building may consist of (1) continuous walls, (2) a series of piers either built in place or precast, (3) a combination of walls and piers, (4) a concrete slab laid on the ground, (5) wood posts, or (6) wood sills. The essential features necessary for the successful use of the various types are discussed under the above headings; also the thickness of walls and dimensions of piers for medium-sized structures other than heavy storages are suggested. Requirements for cellar walls are given on pages 18–21.

It is necessary that foundation footings be made wide enough to support the structure on the kind of soil to be built on. The characteristics and bearing power of various soils are given on p. 3. The general method of calculating the weight on footings is given on pages 38–44. It can be used where buildings are heavy or are of a different character from those described under Types of Foundations.

SELECTING A SITE

A building site on a slight elevation having good drainage and a firm subsoil is to be preferred. Unless well settled, filled ground generally causes trouble. A dump or a site where earth has been deposited calls for careful examination because variation in the depth of fills and different kinds of soil or waste material will cause wide variation in supporting power. Spongy or peaty lands are unsuitable to build

[1] Deceased.

upon unless special design is provided. Investigate steep hillsides to make sure that surface and ground water from higher elevations can be kept away from the foundations and that the site is not likely to become saturated in wet seasons. Early spring or the wet season are the most favorable times to determine critical ground-water conditions. Soils that become very soft when wet are not desirable.

SOIL CHARACTERISTICS

The soil upon which the foundation rests is called the bed and must support the weight of the structure. Clay becomes plastic when wet and under even moderate pressure squeezes out from beneath the footings. The bearing power of clay soils can be improved if they are drained and compacted by ramming in a layer of gravel or cinders. Before building on dry clay make certain it will not swell excessively when wet; some clays swell enough to lift buildings. Heaving of damp clays due to freezing can be reduced if the bed that the foundation rests upon is below the depth of freezing.

A sloping clay stratum may permit sliding of the bed or the foundation. Especial caution is needed where foundations are stepped (see page 8) in clay or sand, to keep these soils from being squeezed or washed from the upper footing levels. When it is necessary to build on compressible soil, the bed must be level and never higher than the adjacent excavations; such soil must be confined so it cannot be squeezed out or washed from under the foundations.

In general the probability of confining soft soils is increased by carrying the foundations deeper, by proper drainage, and by using extra-wide footings to distribute the weight of the structure over a wider area.

When soft soils overlay a more compact stratum, better bearing can be secured by making holes through the soft soil to the firm stratum and filling them with concrete. A reinforced beam or footing may then be built on top of these piers.

Wet soils or localities where the bed is likely to be covered by water require special treatment. Drain tile or blind drains around the foundation will frequently keep water from the bed.[2] Drains placed just above the bottom of footings and sloped so as to conduct water to a lower level, some distance from the site, are effective if provided with a suitable outlet that will not be stopped up. Blind drains are used when tile is not at hand. They are merely trenches 1 to 2 feet wide filled 1 to 3 feet deep with coarse stone, gravel, or other material to form a channel through which water will flow. Before the trench is backfilled, bags, straw, or brush are sometimes laid on top of the gravel to keep silt out of the spaces between the stones. Grading the site to shed surface run-off away from the building, sodding or paving the ground for a distance of about 10 feet around the structure, and intercepting ground water from higher levels are conducive to drier beds.

Flowing water may undermine footings resting on a foundation bed of sand. However, care must be taken that damp sand, after being built upon, is not allowed to become dry because of drainage to lower excavations in the vicinity or to become saturated by flooding from

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[2] Methods of intercepting surface drainage and ground water are given in detail on pages 8 to 11 of U. S. Department of Agriculture Farmers' Bulletin 1572, Making Cellars Dry.

pipe trenches. Damp sand shrinks and settles upon becoming dry and swells or flows if water is added; either change may make the foundation insecure.

Soils differ in bearing power and also may have peculiarities that must be understood; therefore, it must not be assumed that any one soil will behave the same under all circumstances or be of the same character at different distances below the surface.

In localities subject to earthquakes local experience has developed safe methods of building.

TEST BORINGS

A practical method for determining the character of the underlying strata is to make excavations and borings at several points on the site. If holes or trenches are dug to the bottom of the foundation and then borings are made with a post auger to 5 feet below the bed, it can be seen whether the bed extends down uniformly and level or changes decidedly in nature and slope. Note the auger samples for each foot of depth and compare them with the soil classification below so as to determine what weight the bed will support.

If water rises in the bored holes, it is best to seek the advice of builders or engineers acquainted with local conditions as the nature of the soil may be radically changed when wet. If the water cannot be diverted economically, a safe foundation may be expensive.

SOIL BEARING VALUES

The weight a soil will safely support cannot be accurately determined without making extensive load tests, but experience has shown the loads given below to be reasonable under average building conditions.

Safe load on 1 square foot for various soils:	*Pounds*
Hard rock	30, 000
Soft rock	16, 000
Gravel or coarse sand, well consolidated	12, 000
Dry, hard clay or coarse firm sand	8, 000
Moderately dry clay or moderately dry coarse sand and clay	4, 000 to 6, 000
Ordinary clay and sand	3, 000 to 4, 000
Soft clay, sandy loam, or silt	1, 000 to 2, 000

FOOTINGS

The footing is the base of a foundation and transmits the superimposed load to the bed. A builder will save trouble and money if he makes certain, before starting work, that the type and size of the foundation footings are suitable for his soil conditions and also that the footing will be far enough in the ground to be protected from frost action (fig. 1), erosion, and the rooting or scratching of farm animals. This applies especially to permanent or large buildings whether the foundations are continuous walls or piers.

Poured-concrete footings are more dependable than those of other materials and are recommended exclusively for farm buildings when loads are heavy. When the walls are of unit masonry such as brick, concrete block, etc., it is good practice to make the lower 4 or 6 inches of concrete at least as wide as the wall, especially where hollow units are used, because the concrete, while plastic, fills up irregularities in the

bed and arches over soft spots; this might not be the case when large stones or other masonry units are used for footings. Also a level and smooth surface will be provided for starting the masonry above. It is advisable to place at least two ⅝-inch reinforcing rods, spaced not over 8 inches apart extending the length of the foundations, about 3 inches down from the top of the footing.

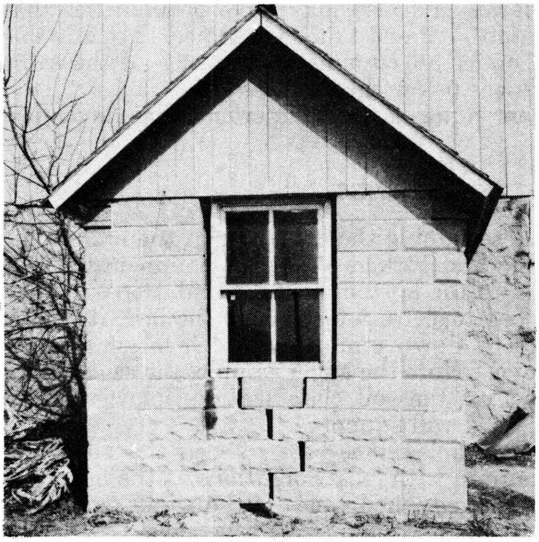

FIGURE 1.—The heaving, by frost, of the shallow footing, cracked the wall at its weakest point.

DEPTH BELOW GRADE

The depth generally considered safe in various regions is given in table 1. However, it is best to check with local builders or county agricultural agents because safe depth varies to a great extent, depending usually on the depth to which frost penetrates and the effect of frost in the soil. Dry soils ordinarily do not heave when freezing, but damp clay may heave enough to cause serious damage to the building unless the footings are below frost depth.

The depths given in table 1 are based on recommendations made by the state agricultural colleges and are considered sufficient to prevent damage by frost but are not the total depths to which frost penetrates. Note the soil conditions at these depths; if not firm or if subject to change of volume due to alternate wetting and drying, footings must be made wider, reinforced, or carried deeper than indicated in the table.

TABLE 1.—*Suggested depths for placing bottoms of footings*

[Figures in column A apply to milder areas; those in B to colder areas]

State	Light buildings, chicken houses [1]		Farmhouses [2]		Heavy permanent barns and storages		Local considerations
	A	B	A	B	A	B	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
Alabama	12	12	18	18	18	18	Reinforce footings and floor, and use piles in Blackbelt area.
Arizona	12	20	18	36	18	36	Closeness of irrigation a factor.
Arkansas	12	12	16	16	18–24	18–24	Continuous foundations preferred.
California	6	12–18	6–12	18–24	12	24–30	
Connecticut	12–24	12–24	24–42	30–48	24–42	30–48	
Florida	surf	surf	surf	6–12	surf	6–12	Wide footings near surface; sandy soil.
Georgia							Conditions variable; seek local advice.

[1] Not for 2-story poultry houses.
[2] Where depth is 48 inches and over, basements are generally used.

TABLE 1.—*Suggested depths for placing bottoms of footings*—Continued

State	Light buildings, chicken houses		Farmhouses		Heavy permanent barns and storages		Local considerations
	A	B	A	B	A	B	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
Idaho	12	18	24	36	36	48	
Illinois	12	12–18	42	66	30	42	Reinforcement advised.
Indiana	18–24	18–24	24–36	24–36	36	36	
Iowa	18	20	36	42	36	42	
Kansas	24	24	60	60	48	48	Reinforce; heavy footings needed on swelling and shrinking soils.
Kentucky	18–24	18–24	18–24	30	30	30	
Louisiana	2–12	2–12	2–12	2–12	2–12	2–12	Wide footings on alluvial soils.
Maine [3]	48–60	60–72	48–60	60–72	48–60	60–72	
Maryland	-------	-------	-------	-------	-------	-------	Conditions variable; seek local advice.
Massachusetts	24–48	24–48	24–48	24–48	24–48	24–48	Soil conditions fairly uniform.
Michigan	[4] 18	24	36	36	36	36	
Minnesota	12	18	60	60	[5] 18	[6] 36	
Mississippi	9	9	([7])	([7])	([7])	([7])	
Missouri	12	18	18	24	24	30	
Montana	-------	-------	-------	-------	-------	-------	Seek local advice.
Nebraska	12	18	18	24	18	24	Guard against roof water and rooting animals.
Nevada	0–6	18	0–6	18	12	24	
New Hampshire	36	48	72–96	72–96	48	72	
New Jersey	6–8	24–30	16	36	[8] 16	[8] 36	
New Mexico	6	6	9–12	12–15	12–15	15–20	
New York	36	36	48	48	48	48	
North Carolina	12	30–36	24	30–36	24	30–36	
North Dakota	18	18	18	18	18	18	Reinforce.
Ohio	18	18	18	18	18	18	Do.
Oklahoma	12	18	18	24	24	24	
Oregon	18	24	12	24	24	24	
Pennsylvania	36	-------	48–72	48–72	48	48	
South Carolina	10–12	12	14	18	14	18	
South Dakota	18	18	54	54	24	24	For frame buildings use continuous foundations.
Do	42	42	60	60	48	48	For masonry buildings use continuous foundations.
Tennessee	12	12	24	24	24	24	Guard against termites.
Texas	8	8	12	30	16	30	Guard against erosion.
Utah	12	20	20	30	30	34	
Vermont	12	12	60	60	60	60	Conditions vary widely; carry to firm soil.
Virginia	24	24	24	24	24	24	
Washington	-------	-------	-------	-------	-------	-------	Conditions variable; seek local advice.
West Virginia	18–24	24–30	18–24	24–30	24	30	
Wisconsin	30	42	36	48	[9] 36	[10] 42	

[3] Use batter on outside face of wall or use a footing; less depth is required in gravelly soils.
[4] For snow-protected ground.
[5] Wooden barns.
[6] Masonry barns.
[7] Depth to uniform soil.
[8] Footings for storage structures reinforced.
[9] 48 inches if building is unheated.
[10] 54 inches if building is unheated

In regions having little frost set footings below the topsoil on firm ground, because if they are placed too close to the surface, rats can burrow under them and wind, rains, or floods may erode the soil (fig. 2) from beneath, causing the building to settle. In some localities the firm soil is a relatively thin layer overlaying soft ground. If the firm soil is cut through, a secure bearing is almost impossible. Under such conditions shallow footings may be protected from erosion by banking soil against the foundations (fig. 3). This fill requires sodding

and protection from erosion caused by drip from the roof, which has been provided with rain gutters and downspouts.

All footings of buildings are preferably set on the same type of soil

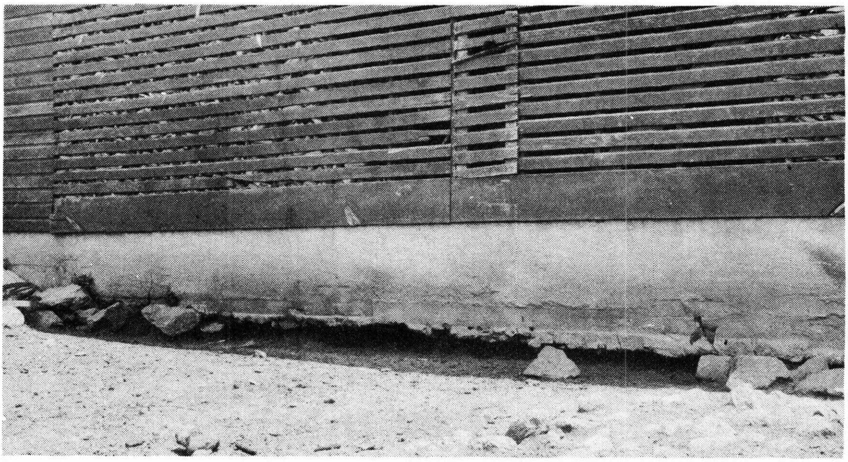

FIGURE 2.—A shallow foundation undermined by erosion.

and must be level but not necessarily at the same elevation. Where the ground slopes or where there is a basement under only a portion of the building, step the footing down gradually to avoid undermining the higher portion (fig. 4). The ratio in which the stepping can be done safely varies with the type of soil, but for average conditions a vertical rise (*V* in fig. 4) of not more than 2 feet in a horizontal distance (*H* in fig. 4) of 4 feet is generally satisfactory.

When one part of the foundation rests on rock and another on soil make the footing of the portion on soil twice as wide as called for on page 39. Under such circumstances some building codes require the rock surface to be cut so a 6-inch layer of sand can be placed on top of the rock. Occasionally a relatively thin rock stratum overlays soft clay or loose sand; such a bed is unsafe for heavy buildings or concentrated pier loads. Care must be taken to see that the rock is not merely a large boulder that might be loosened by the weight of the building.

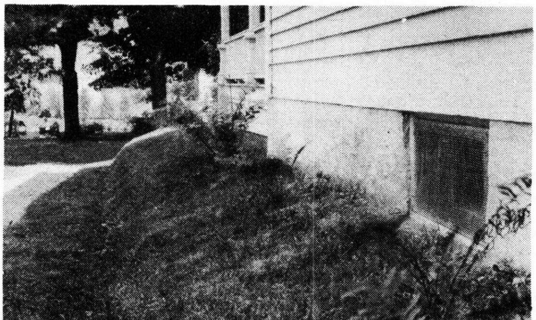

FIGURE 3.—A shallow foundation protected by a well-sodded earthbank.

When the rock stratum slopes, the surface may be cut to form level steps to prevent the footing from sliding. Sometimes slight slopes are

merely heavily chipped; at times the surfaces are dowelled. Where outcroppings of rock strata have been exposed to weathering for some time and the surfaces are likely to be rotten or loose, cut the rotten layers away to solid material.

Most footings, except those on solid rock, settle to some extent, but this settling does no harm unless it is excessive or uneven. Unequal settling must be guarded against as it is bound to crack plaster, bind doors, or rack floors and frames.

AREA OF FOOTINGS

Unequal settlement can be avoided by proportioning the areas of the footings to the loads from different parts of the building; footings on soft soil must be larger than those on firm soil.

In good firm soil and when the load is not heavy a footing may not be required to distribute the load, but a concrete footing the same width as the wall is desirable under unit masonry.

The required area of a pier footing in square feet is obtained by dividing the total load, including the weight of the assumed pier and its footing, by the allowable unit load on the soil, as given on page 3. The width of a wall footing in feet is found by dividing the load per linear foot on the wall, including the weight of the assumed wall and its footing, by the allowable unit load on the soil.

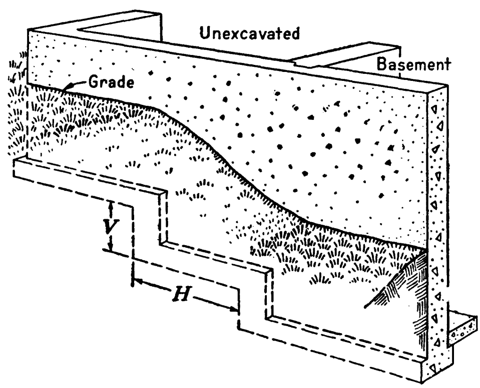

FIGURE 4.—Method of stepping wall footings.

A detailed method of estimating loads, wall thickness and width of footing for both walls and piers is explained by two examples on pages 40 to 44 for the use of those who wish to check the required size of footings for special buildings and unusual methods of loading.

The size of walls and piers commonly used for ordinary farm buildings are given on pages 39 and 40. For practical purposes a footing projecting 4 inches each side of the wall is reasonably safe where the soil will support 1½ tons per square foot or more. If the soil will support only 1 ton the footing may have to be 24 inches wide, and it would be advisable to check the necessary width by the method described on page 38.

Where piers spaced 6 to 8 feet apart support a one-story frame house a footing 20 inches square is advisable on a soil that will support 1½ tons per square foot. When only one or two columns 10 to 12 feet apart are used, as in basements, to support a girder and the outside walls are carried on a full foundation wall a column footing at least 24 to 30 inches square may be needed. Likewise in two-story barns the footings of columns which generally carry girders 10 feet 6 inches long may have to be 24 to 30 inches square.

The footings shown on plans available from most of the State agricultural colleges and from other reliable sources are designed to

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support the structure safely on a medium soil (usually the kind that will hold up 1½ to 2 tons per square foot). The size of the footing must be increased if the soil will hold up less than 1½ tons or if other unfavorable conditions exist. Experienced local builders or engineers can usually give reliable advice; also the building codes of nearby cities are helpful guides where one is in doubt as to the load a soil will support safely.

THICKNESS

In general, the thickness of concrete footings, which are the only kind recommended, must be not less than 1½ times its projection beyond a pier or wall. For instance, if the footing under an 8-inch wall is 16 inches wide it will project 4 inches beyond each side of the wall and therefore will be 6 inches thick. If the footing were 32 inches instead of 16 inches it would project 12 inches and would be 18 inches thick. Sometimes in firm ground, if forms are not needed, the earth sides at the bottom of a trench are sloped out, so as to provide a greater bearing area for the wall; by doing this a wide trench, that would be necessary if a regular footing were to be used, is avoided. Concrete can be saved by stepping large thick footings (fig. 5).

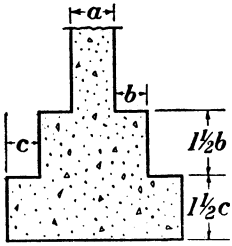

FIGURE 5.—Concrete can be saved by stepping footings. The vertical drop is made one and one-half times the horizontal projection (*b* or *c*) beyond the next upper course or pier.

Large footings are more economical if made of reinforced concrete as the required thickness is much less than for plain concrete. Plain concrete footings, if stepped when large, can be made economically for most farm buildings. Reinforced footings if necessary, except as noted on page 4, require an engineer's advice.

BONDING

The foundation wall must be bonded to the footing, especially when subjected to earth pressures; several methods are suggested.

Rods ½-inch in diameter and 8 to 12 inches long, spaced 16 inches apart, may be embedded one-half their length in the footing and allowed to project into a concrete wall above. Laying a 2- by 4-inch or 2- by 6-inch timber, bevelled on two edges, in the top of the concrete footing is a very effective method of forming a key; this piece is removed when it dries out after the footing hardens. Good-sized stones may be placed about 2 feet apart and set to half their depth in the soft concrete footing for bonding rubble stone walls.

In earthquake territories it is advisable that pier or column footings for important buildings be designed by an engineer familiar with such construction.

TYPES OF FOUNDATIONS

CONTINUOUS WALLS

Continuous foundation walls (fig. 6) cost more than pier foundations but afford greater security and are desirable, especially if the building

must be warmed or is subjected to heavy wind or earthquakes or if rodents must be kept out.

Special features to be observed for foundations of certain structures are given in various Farmers' Bulletins.[3]

In general, foundation walls 8 inches thick of concrete, block, brick, or tile are ample for one-story wooden farm buildings no heavier than the farmhouse; rubble stone walls must be not less than 16 inches. If the superstructure has masonry walls or is a long two-story frame building, foundations 12 inches thick will be advisable—18 inches thick if of rubble stone.

Solid concrete and brick walls are desirable for buildings with heavy loads because of their high resistance to crushing. (See table 2.)

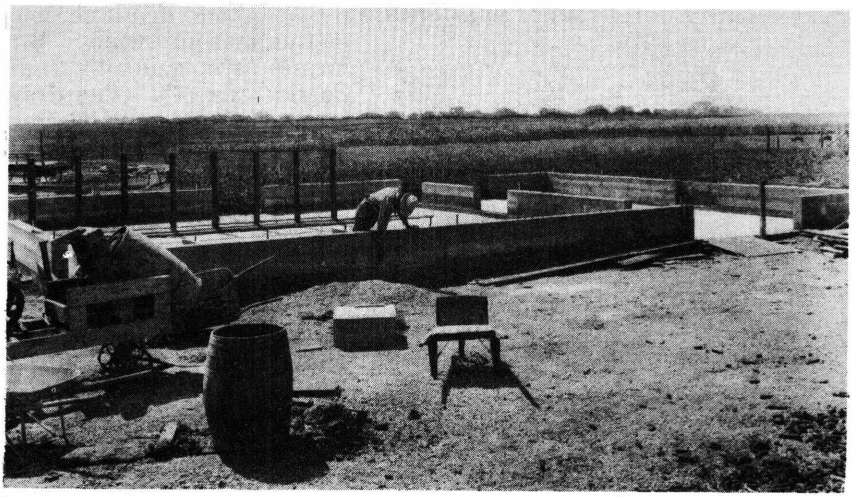

FIGURE 6.—A well-built continuous-wall foundation.

Hollow units are used for the walls of many farm buildings and are strong enough for ordinary purposes.

Termite protection is important, especially where hollow units are not filled, because mud tubes will be unnoticed if the insects build in them.

Rubble stone laid in cement mortar makes a strong, durable foundation. Dry stone walls without mortar are occasionally used for lightweight structures but are unreliable.

Frame buildings must be anchored to continuous foundations by ⅝- or ¾-inch bolts spaced 6 to 8 feet apart to resist wind and flood. Bolts extending less than 12 to 18 inches into concrete walls and 2 to 3 feet into walls of block, tile, brick, or stone are likely to be pulled out of the foundation. By bedding the wood sill in cement mortar an even bearing is provided for the superstructure. If the foundation is likely to be damp, coating the top of the masonry with tar checks somewhat

[3] See List, p. 45.

the moisture rising by capillarity to the superstructure; metal termite shields (fig. 12) extended across the top are effective.

The voids of hollow units must be filled with concrete around anchor bolts and for two courses under girders or other concentrated loads. Crumpled paper, tucked down the wall, will prevent concrete from dropping lower than it is needed.

Reinforcement at the corners of buildings prevent cracks in concrete foundations which very commonly occur at the intersection of walls. Half-inch rods 6 feet long are usually bent into ells and laid in the center of the wall at each 8 inches of height so that one leg of each projects into the end wall and the other into the side wall. Where a long or high concrete wall is exposed to temperature changes special reinforcement may be advisable.

Frequently buttresses or pilasters are required to stiffen high, long, or thin masonry walls. Buttresses are generally built outside (fig. 7). The drawings of a properly designed structure generally indicate the location, size, and type of expansion joints, buttresses, and reinforcement needed for long buildings or other special provision. Types of expansion joints for general purposes are discussed on pages 25, 26, and 31 of Farmers' Bulletin 1772, Use of Concrete on the Farm.

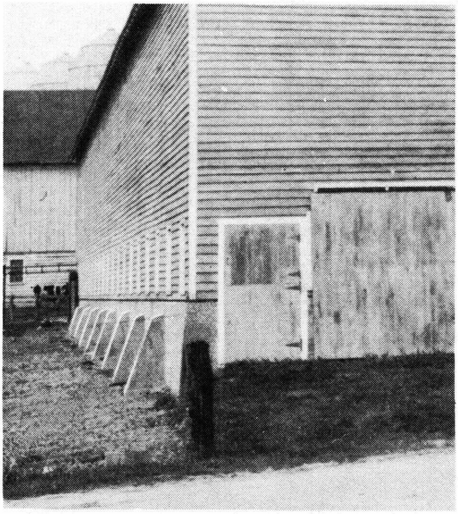

FIGURE 7.—Buttresses on the outside have the advantage over inside pilasters as the side alleys are not narrowed and smooth inside walls are obtained.

The space enclosed by the foundation beneath the floor, when there is no cellar, must be well ventilated (fig. 8, *A*) to prevent the decay of the sills and joists and warping of floors. Vents less than 1 square foot for each 15 linear feet of wall are too small. Also it is desirable to make the vents so that when screened they will act to exclude rodents or other animals. In cold locations the vents can be closed in winter.

The top of the foundation must be at least 18 inches above grade to keep water from splashing the woodwork, and higher if access to the space under floors is desired. When the soil is of an open type that has natural drainage, the ground under the building sometimes is excavated lower than the outside grade to secure working space. This does not cost as much as making a higher foundation.

PIERS

Where warm floors are not required, the use of piers for the foundation (fig. 9) is common for permanent buildings without cellars. They are more economical than continuous walls, can be made quite

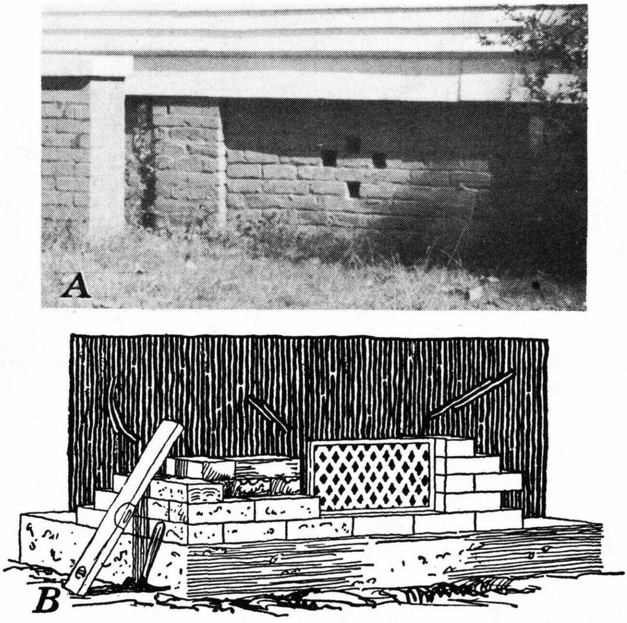

FIGURE 8.—*A*, A common type of ventholes which are not large enough and are difficult to screen; *B*, a cast-iron grill which is easily built in and can be readily closed in winter by stuffing bagging behind it. These are made in sizes varying from 4 by 8 inches to 12 by 24 inches.

substantial, and afford good ventilation of floor timbers. Frequently curtain walls are built between piers for warmth.

The spacing of piers depends upon soil conditions and load (fig. 10) supported. Ordinarily spacing is limited to 8 to 12 feet, but under

FIGURE 9.—Well-bonded brick piers on ample footings make a good foundation in warm regions.

buildings used for bulk storage a much closer spacing may be needed. Piers are bonded to ample footings of concrete as explained on page 13.

Brick or reinforced concrete only must be used for heavy loads or high piers. Concrete block, hollow tile, and rubble stone are used for short, lightly loaded piers; where permanence is desired, the voids of hollow units may be filled with concrete; 8- by 16-inch concrete blocks are safely used for porch piers up to 3 feet high if a firm concrete footing is provided.

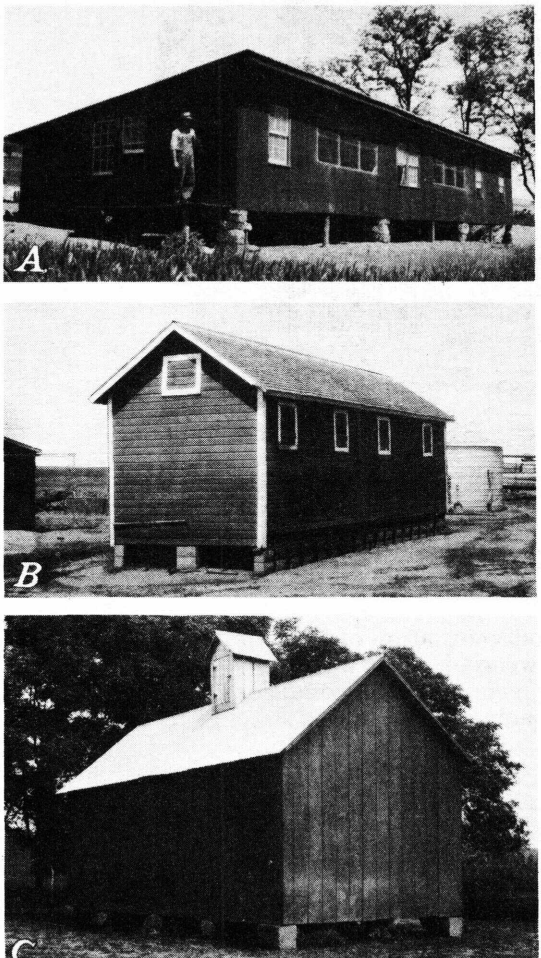

FIGURE 10.—*A*, A poor foundation. Since the posts are too small to resist rot for long and the sills between posts are too small, makeshift piers of loose stone have been provided. Because they do not weigh much, many poultry houses are built on such foundations. *B*, Closely placed masonry piers under a heavy storage. *C*, Boulders that may soon settle from erosion and rack the building beyond use

Piers of unit masonry, especially those of rubble stone, must be well bonded and have their voids filled with concrete. For strength, stone piers require frequent bond stones with level top and bottom surfaces extending the full width of the pier.

The smaller side of a pier for a large building must be not less than 12 inches if of brick or concrete, 16 inches if of hollow units, and 18 inches if of rubble stone. The height above the top of the footing is preferably limited to 10 times the small side for brick or concrete and 5 times for hollow units or rubble stone.

Table 2 gives safe loads in pounds per square inch on piers that are loaded on their center lines. A pier that is loaded close to or at its edge, needs to be safeguarded against a tendency to tilt, by increasing its size and increasing the projection of the footing on the side of the heaviest load.

Concrete piers 3 to 4 feet high usually require a ⅜-inch rod in each corner, extending into the footing with a hooked end (fig. 11, *A*). Piers 4 to 6 feet high, need reinforcement such as is shown in figure 11, *B*. Special advice is required for reinforcing larger piers. Tall piers can be built more easily if dowels (short lengths of the reinforcing) are set so as to project 18 inches above the footing when the concrete is poured (fig. 11, *B*). Set each dowel accurately so the corresponding pier rod will be properly located when the two are wired together.

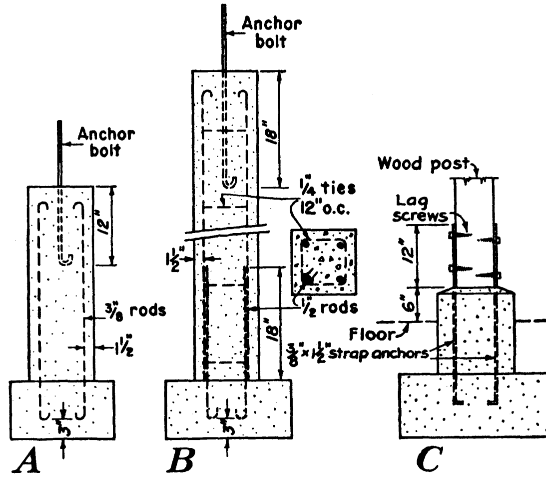

FIGURE 11.—*A*, Method of reinforcing and anchoring short piers; *B*, method of reinforcing larger piers (note how the dowels are wrapped to the reinforcement with baling wire); *C*, method of anchoring wood posts.

Bolts five-eighths or three-fourths of an inch in diameter, for anchoring the superstructure, usually are extended about 3 feet into piers of unit masonry and 12 to 18 inches into concrete piers and projected above the masonry a sufficient height for bolting down the sills or girders. The lower end of bolts may be hooked or provided with a substantial washer. Figure 11, *C*, shows a method of anchoring wood posts.

TABLE 2.—*Safe loads in pounds per square inch for piers*[1]

Height of pier	Concrete 1:2:4 mix	Hard brick		Rubble stone		Hollow units [2]	
		1:3 cement mortar	1:1:6 cement-lime mortar	1:3 cement mortar	1:1:6 cement-lime mortar	1:3 cement mortar	1:1:6 cement-lime mortar
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Five times small side or less	400	200	175	140	100	80	70
Ten times small side or less	300	150	130				

[1] Based on full area of pier.
[2] If hollow units are filled with concrete the values given for brick may be used.

In some localities termites cause extensive damage, and special methods of protection are needed.[4] In localities where termites exist, the wood in the superstructure can be protected by capping the piers with metal (fig. 12).

Heavy winds show up mistakes or carelessness in foundations, as seen in figure 13, especially when poor concrete is used.

[4] U. S. Department of Agriculture Farmers' Bulletins 1911, Preventing Damage to Buildings by Subterranean Termites and Their Control, and 1993, Decay and Termite Damage in Houses.

PRECAST CONCRETE POSTS

Precast reinforced concrete posts and piers are commonly used for small structures. They are economical if made a few at a time as the same forms may be used over and over. Precast posts must be made of good concrete and cured for 28 days before they can be moved into place with safety.[5] The size is limited by the weight and transportation facilities. A 6- by 6-inch concrete post 4 feet long weighs 145 pounds; an 8- by 8-inch post weighs 260 pounds.

Care must be taken to anchor the posts in the ground to prevent withdrawal (fig. 14). This can be effectively done by providing a poured concrete footing that will form a secure bond so that the pier and footing will not become separated. The footing will afford extra bearing, thereby lessening soil pressure. Figure 15 shows how to build a footing for precast posts; ⅝-inch dowels in the bottom of the post provide a good bond. Ends of larger rods may be hooked as in figure 11.

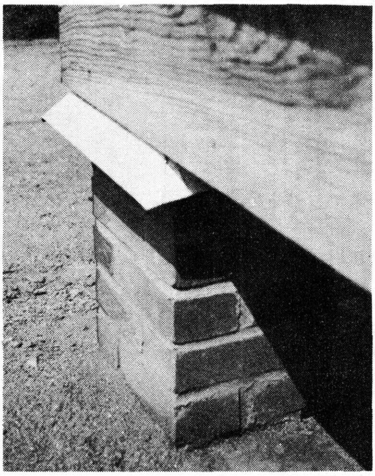

FIGURE 12.—Termite shields last longer if of rust-resistant sheet metal. The 3- to 4-inch overhang prevents insects crawling past the metal barrier.

CONCRETE-SLAB FLOORS

In regions where frost is not a consideration, lightweight one-story buildings are sometimes built on a concrete slab which also serves as the floor and foundation (fig. 16). In such cases it is advisable to extend an apron under the edges of the slab to avoid erosion; sometimes the aprons are precast slabs stood on edge. Where a structure is to be used only 2 or 3 years a temporary foundation of concrete blocks or sound building tile can be utilized, as in figure 17, provided the soil is dry and is not overloaded. When slab floors are used for moderately large or large structures or when the wall loads are heavy, the floors are thickened at the edges (fig. 18) to prevent cracking the slab. Reinforced slab foundations are occasionally used to save deep footings. These are preferably designed by an engineer and are not recommended where heaving of the soil is severe enough to damage the building or when alternate freezes and thaws occur frequently.

TIMBER FOUNDATIONS

For temporary structures and for many smaller farm buildings timber foundations are economical easy to install, and fairly durable when properly protected.

Posts

Posts of carefully selected heartwood from rot-resisting species like cedar, cypress, redwood, white oak, chestnut, or black locust are

[5] U. S. Department of Agriculture Farmers' Bulletin 1772, Use of Concrete on the Farm.

preferred; the first three are resistant to termites. Wood having narrow growth rings is better than fast-growing stock. If a durable species is not available the wood can be treated with a preservative to guard against rotting or attack by termites, which are very destructive in some localities.

Several kinds of preservatives for wood posts are used. All of them

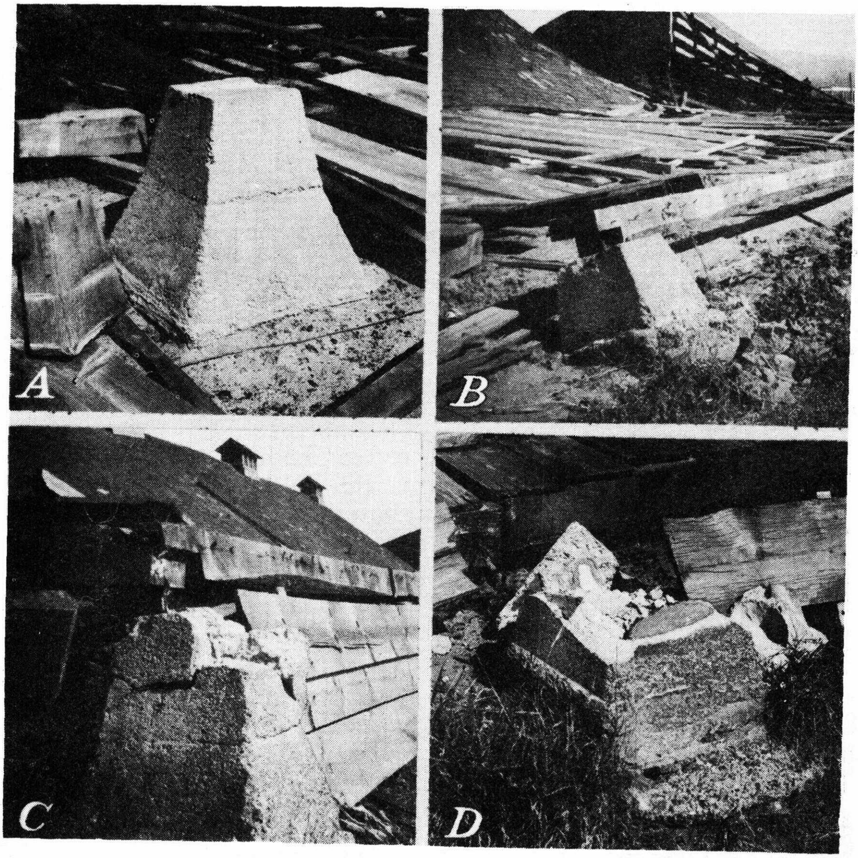

FIGURE 13.—*A*, A well-built pier securely doweled to the footing—the anchor bolt to hold the sill was omitted; *B*, the anchor bolt was supplied for the sill—but the footing was made in a shallow, round hole; *C*, a short anchor bolt could not utilize the ample strength of this pier; *D*, too large sized aggregate was used—the pier failed at its weakest place.

are more effective when applied under pressure. Creosote is the most commonly used preservative on farms, and where pressure-treated timber is not available the serviceability of posts can be materially increased by using the hot-and-cold-bath process [6] for seasoned wood.

[6] See U. S. Department of Agriculture Farmers' Bulletin 744, The Preservative Treatment of Farm Timbers, pp. 13–23 for the hot-and-cold-bath process and p. 23 for the brush treatment.

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Green posts can be treated with zinc chloride by the tire-tube method, or the living tree can be treated by the bucket or stepping method.[7]

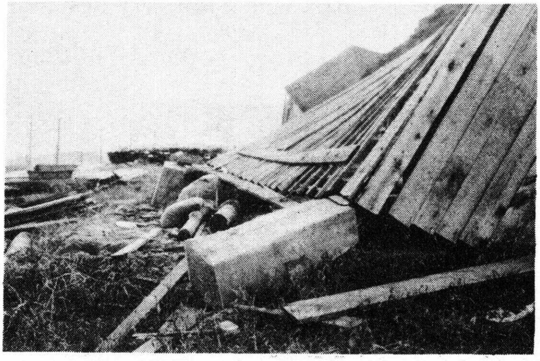


FIGURE 14.—This precast pier, while unusually large in cross section, was not heavy enough to resist withdrawal by high wind against the large barn. A footing would have made it more secure against being pulled.

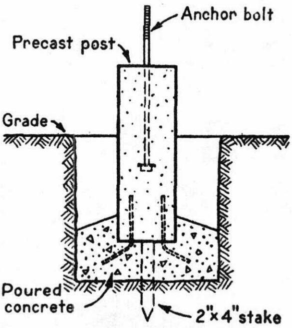


FIGURE 15.—The stake upon which the post rests is used merely to keep the top of the post at the proper height while the concrete footing is soft. It is left in place and eventually rots.

Applying creosote with a brush is least effective and is of little value unless the wood is well-seasoned and dry. However, when treated lumber is used, it is advisable to give all cuts made in connection with framing a saturating brush coat of creosote before the timbers are assembled.

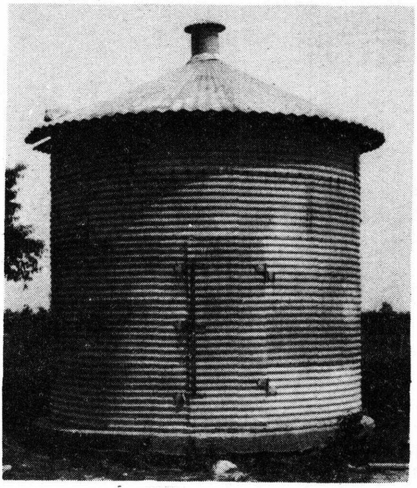


FIGURE 16.—Grain bin anchored to concrete-slab foundation. A gravel fill or heavy sod will prevent erosion of soil from under the slab. (See also figs. 31 and 34, Farmers' Bulletin 1772).

When posts are used to support buildings set the butts down to a depth of 3 or more feet, depending upon the frost line and the nature of the soil, and backfill around them with porous material like gravel or cinders, making the top layer of well-packed gravelly clay. Their tops are then fastened together by sills or cap logs, and if the ground is soft or the posts extend several feet above ground or if the supported structures are subject to heavy wind or earthquakes, the posts must be braced with plank diagonals. Also cleats or anchors nailed to the posts below ground increase resistance to withdrawal by wind and frost action.

The spacing of posts depends on the load they carry. A 7- or 8-inch post, such as is commonly used, will, under average conditions, support a load of 1,000 pounds.

[7] R-1158, Tire-Tube Method of Fence-Post Treatment (mimeograph). Applv, U. S. Forest Service, Forest Products Laboratory, Madison, Wis. Also U. S. Department of Agriculture Farmers' Bulletin 1582, Protection of Log Cabins, Rustic Work, and Unseasoned Wood From Injurious Insects.

In accordance with common practice these posts are spaced 6 to 8 feet apart in rows 6 to 8 feet apart on centers under one-story farm-

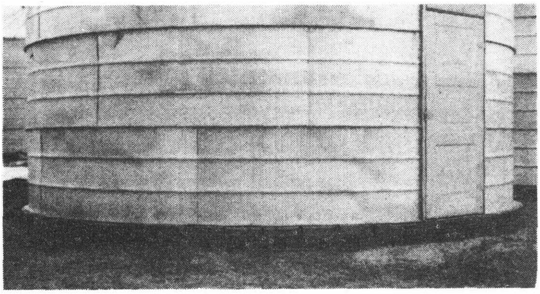


FIGURE 17.—Tile blocks laid flat without mortar joints. Note several courses are used to step up the foundation on sloping ground.

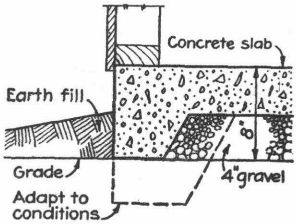


FIGURE 18.—Method of increasing the thickness of a slab under walls; sometimes the footing is extended below the surface to guard against erosion.

houses, small corncribs, and buildings of similar construction and height. Masonry piers or continuous foundation walls (fig. 19, *B*)

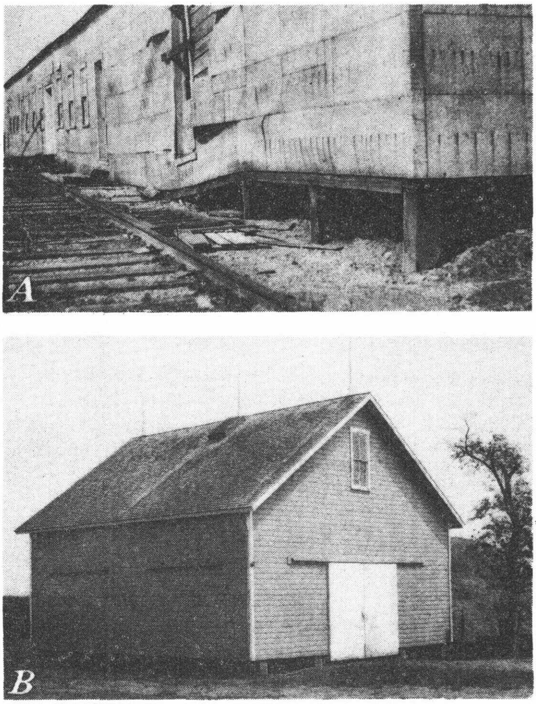


FIGURE 19.—*A*, Posts could not carry the weight of this building. The sill over the first post was weakened by being halved. *B*, This building sets on secure continuous masonry walls that will not allow it to settle. As end walls are not needed to carry the weight, ample ventilation is secured under the floor.

are more reliable supports for storehouses such as large granaries and corncribs, two-story barns, etc., than are wooden posts (fig. 19, *A*). If a greater load-bearing value is needed on individual posts or the ground is soft, a flat stone or a concrete footing can be provided in the bottom of the hole and the post stood on it.

Heavy, solid sills may be secured to the posts by driftbolts, as shown in figure 20. Splitting is avoided by boring holes one-sixteenth to one-eighth inch less than the diameter of the bolts in both the sill and the post. Cap logs may be secured to posts with wood-splice blocks or metal straps. If a plank sill is used, the top of the posts may be cut back to form seats (fig. 20, *C*) and the planks spiked to the sides and top.

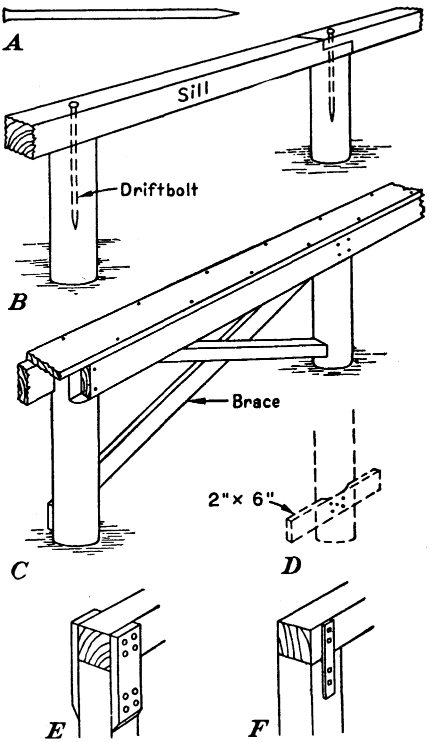


FIGURE 20.—Details of wood-post foundations: *A*, Driftbolt, usual size about ¾ by 16 inches; *B*, solid sill driftbolted to post; *C*, built-up plank sill spiked to posts; *D*, short piece spiked to bottom of post for anchorage; *E* and *F*, two methods of fastening heavy sills to posts.

Mudsills and Runners

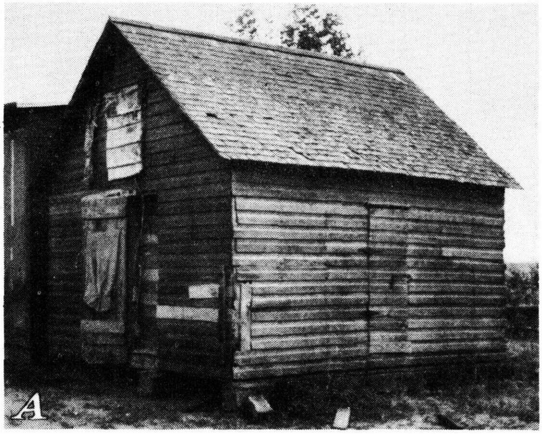
Often mudsills (heavy timbers or hewn logs laid flat on the ground) (fig. 21, *A*) are used for lightweight or temporary farm buildings, and runners or skids (fig. 21, *B*) are used for movable equipment. Such foundations are not very durable but are frequently warranted on account of their low cost and because they make moving possible. Raising the base timbers, whether they support a self-feeder, grain bin, or building, about 6 inches above the ground on flat rocks or short lengths of logs, protects them from ground moisture and permits the air to circulate around the floor framing. A good plan is to insert a piece of asphalt roofing or galvanized metal between the sill and the blocking to prevent absorption of water from the ground. If the metal projects over each side of the sill it will guard against termites. The base timbers will be better protected if the vegetative soil under the building is removed and 6 or 8 inches of gravel or sand is spread over the site.

CELLAR WALLS

The walls of cellars, in addition to supporting the superstructure safely, must generally withstand lateral pressure from the earth outside and keep out water and moisture. Sometimes excavations are made inside the foundations in firm-standing earth to provide for a heating plant or for storage. (See p. 34.) Solid walls of well-proportioned concrete [8] usually meet these requirements without other precaution than drain tile around the outside footing (fig. 22). Hard

[8] The method of making well-proportioned concrete is given in U. S. Department of Agriculture Farmers' Bulletin 1772, Use of Concrete on the Farm.

brick, stone, and sound concrete block, laid in cement mortar, make good cellar walls when waterproofed and stuccoed on the outside below grade. Hollow clay tile and cinder concrete block with watertight plaster on the outside, are sometimes used for foundations of



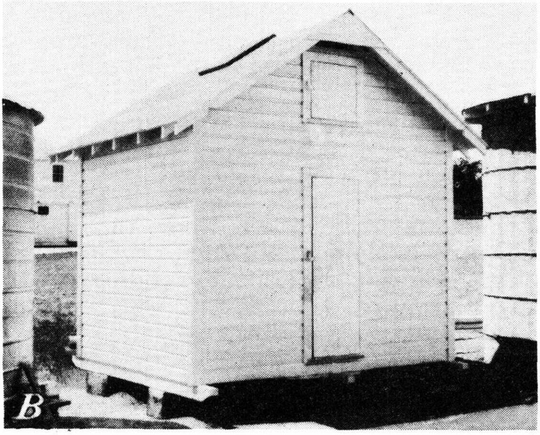


FIGURE 21.—*A*, A building supported on mudsills resting on the ground, where they will rot in a short time. If the sills are raised off the ground, as shown in *B*, they last longer and reduce harborage for rats.

frame buildings, but tile has low resistance to earth pressure, while cinder blocks are apt to soften in contact with wet earth and are more suitable for use above grade.

The required thickness of walls depends largely on the depth of the cellar below grade and also the weight and length of the superstructure. A clear height for cellars below the first-floor joists of 6 feet 9 inches is usually considered the minimum for convenience in farmhouses; a greater height is often required for locating the ducts of a warm-air furnace and for storage cellars. Unless areaways are provided, set the top of the foundation wall for farmhouses at least 2 feet above grade to permit windows for light and ventilation (fig. 23).

Under ordinary conditions where the outside grade is not more than 6 to 8 feet above the floor, a wall thickness of 18 inches for rubble stone and 12 inches for concrete or unit masonry are advisable. For walls deeper in the ground increase the thickness 4 inches for each additional 4 feet in depth. Also a greater thickness may be necessary for a storage or other heavily loaded building and for high masonry walls.

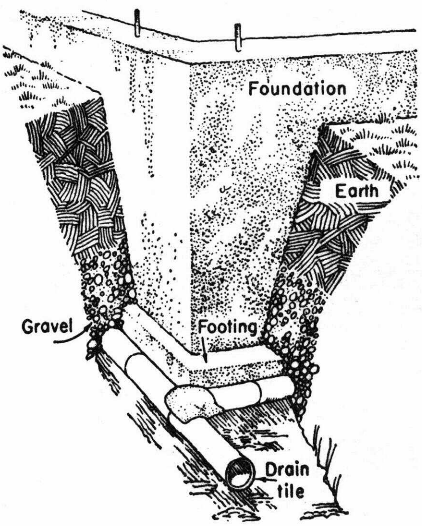


FIGURE 22.—Proper method of laying 4-inch drain tile around the footing of a building. The tile is laid with open joints covered with 6-inch-wide strips of burlap and surrounded with gravel. The tile must be carried to an outlet lower than the floor.

For two-story farmhouses where the ground outside is not more than 4 feet above the cellar floor an 8-inch wall of concrete, brick, or concrete block can be used safely if ground water is not a problem.

When ground water is higher than the cellar floor, certain construction features must be observed in order to provide a dry cellar. Careful workmanship, impervious masonry, nonleaky joints between the footing and the wall, as well as between hardened and new concrete, waterproofing of the outside of the wall, waterproofing and reinforcing of the floor, tile drains outside the footings, watertight joints where the floor joins the wall, and also where pipes or column footings extend through the floor, proper backfilling, grading of the ground outside to shed surface water,

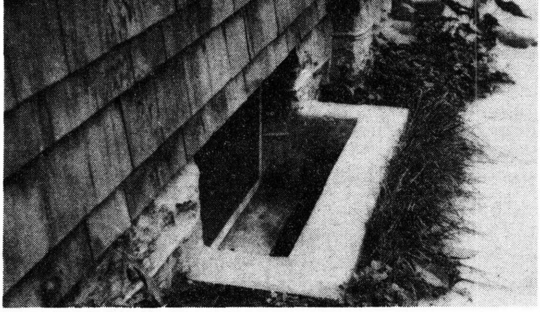


FIGURE 23.—Areaways to permit the use of windows in a cellar when the outside grade is high. The bottoms of the areaway are not paved unless a piped drain is provided. Frequently 12 to 18 inches of gravel is used in the bottom to prevent the accumulation of water.

the use of downspouts and paved spillways, and the use of drains to intercept ground water are items to be considered. The proper

methods of providing these features are given in Farmers' Bulletin 1572, Making Cellars Dry. It is easier and cheaper in the long run to follow the recommendations contained in that bulletin at the time of building than later.

CONSTRUCTION OF FOUNDATIONS

ESTIMATING MATERIALS AND LABOR

The exact quantity of materials and amount of labor required for building walls depend upon various factors which are generally understood by experienced builders. The efficiency of the workmen, the economical lay-out of work to provide convenience in handling the materials, and the thickness of walls and mortar joints vary greatly. The data in tables 3 and 4 will be helpful in estimating approximate quantities of materials and labor for masonry. Excavation, grading, and drainage, if not done by farm labor, are items of cost to be considered. The time required to execute the work, as given in the last column of table 3, is for experienced workmen under good working conditions. Under unfavorable conditions or when there are many corners, windows, or doors, the number of units placed by semiskilled labor will be about one-third the amounts listed. Estimates, including necessary dampproofing, if obtained from builders, are more accurate.

TABLE 3.—*Materials and labor required for building masonry walls*

Kind of masonry	Units per square foot of—		Quantity of mortar per 1,000 units	Units placed by mason and helper in 8 hours
	8-inch wall	12-inch wall		
	Number	*Number*	*Cubic feet*	*Number*
Brick 3/8-inch joints	14	20	13	1,200
Brick 1/2-inch joints	13	19	15	1,200
Hollow tile, 8- x 12- x 12-inch	1		45	140–170
Hollow tile, 12- x 12- x 12-inch		1	60	110–135
Concrete block, 8- x 8- x 16-inch	1.1		30	[1] 250 [2] 200
Concrete block, 8- x 12- x 16-inch		1.1	35	[1] 200 [2] 150
Rubble stone 27 cubic feet per cubic yard of wall			7–9 cubic feet per cubic yard.	80–100 cubic feet.
Cobble stone 27 cubic feet per cubic yard of wall			7 cubic feet per cubic yard.	80–100 cubic feet.

Concrete: See U. S. Department of Agriculture Farmers' Bulletin 1772, Use of Concrete on the Farm, and table 5.

[1] Cinder block

[2] Stone-concrete block

TABLE 4.—*Materials required for 1 cubic foot of mortar (see also table 6)*

Kind	Mix	Cement	Hydrated lime	Sand
		Pounds	*Pounds*	*Cu. ft.*
Cement	1:3	36:3	0	1
Cement plus 10 percent of lime	1:3+1/10	36.3	1.7	1
Cement-lime	1:1:6	18.1	7.4	1
Lime	1:3	0	15	1

TABLE 5.—*Materials for 1 cubic yard* [1] *of concrete*

Type of construction	Mix	Cement	Moist sand	Gravel	Water
		Sacks	*Cubic yard*	*Cubic yard*	*Gallons per sack*
General reinforced and watertight work (basement wall, steps, floors)	1:2½:3½	5.9	0.55	0.77	4½
Mass concrete of moderate strength (not waterproof) (footings, foundation walls)	1:3:5	4.6	.51	.85	6

[1] 1 cubic yard equals 27 cubic feet.

CONSTRUCTION PRACTICES

Preparation of the Site

In selecting the approximate location of the building avoid disturbing desirable trees and provide convenient space for the storage of materials. Temporary shelters for such materials as lime, cement,

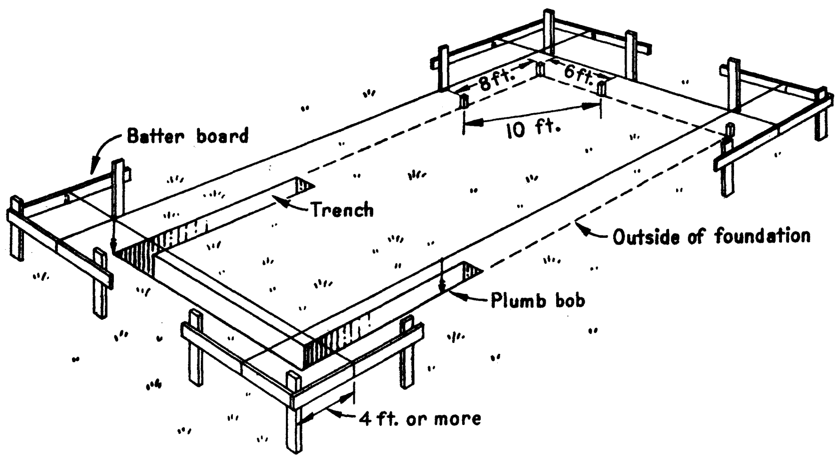


FIGURE 24.—Method of laying out a building.

millwork, and flooring that might be damaged by the weather need to be provided.

The level of the first floor or basement, whichever is the more convenient is generally established in relation to the ground surfaces so as to equalize as much as possible the amount of cut and fill and thus avoid extra handling of earth. It is wise to investigate the feasibility of proper drainage of the final surface and to set the building high enough for basement windows but not too high for proper protection of the footings against the action of frost and erosion.

Locate the basement floor high enough to permit gravity flow for floor drains, basement plumbing, and tile lines outside the footings.

Laying Out the Building

The next step is to establish lines and grades as aids in keeping the work true and level. Figure 24 shows a convenient arrangement of batter boards for lines of a rectangular building.

Small stakes are first located accurately at each corner of the building with tacks driven in their tops indicating the outside line of the foundation walls. To assure square corners, measure the diagonals to see if they are the same length. The corners can be squared by measuring along one side a distance in 3-foot units, and along the adjacent end the same number of 4-foot units. The diagonal will measure an equal number of 5-foot units when the corner is square.

Example:—If one side is 12 feet long and the end is 16 feet, the diagonal is 20 feet for a square corner.

After the corners have been located, three 2- by 4-inch stakes of a suitable length are driven (fig. 24) at each corner 3 to 4 feet beyond the lines of the foundation; then 1- by 6-inch boards are nailed horizontally so the tops of all are level at the same grade. A twine or stout string is next held across the top of opposite boards at two corners and adjusted so that it will be exactly over the tacks in the corner stakes at either end; a plumb bob is handy for setting the line. Saw scarfs one fourth inch deep are cut where the line touches the boards so that the line may be replaced easily if broken or disturbed. After similar cuts are located in all eight batter boards, the lines of the building will be established. Check the diagonals again to make sure the corners are square.

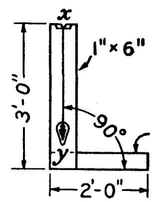


FIGURE 25.—The 1- by 4-inch arm is level when the plumb line coincides with the mark from x to y.

A carpenter's level may be used for establishing levels for small buildings. Figure 25 shows a practical homemade device that may be used in the absence of a level. Large or complicated buildings can be laid out more accurately with surveying instruments.

Excavation

If sod or topsoil are to be saved remove and store them before excavating. Where earth or other materials are handled in wheelbarrows, even for short distances, plank runways permit moving nearly 50 percent more material in the same time and conserve strength. To avoid a second handling, spread as much earth as possible in its final position and reserve only an amount sufficient for backfilling.

Stumps sometimes are left under buildings when the fill is deep enough to cover them. This is not advisable because they may harbor termites or cause settling or difficulty when future additions are made or pipe lines laid; haul them to an out-of-the-way place or pile them together and burn.

Considerable hand labor can be saved in digging deep excavations, as for cellars, if a steep, narrow ramp is left at a convenient point so that a slip can be attached to a long chain and hauled up the slope by a truck or team, pulling from the level above. Earth from dressing the banks plumb and from footings can be dragged up to the ramp with less effort than it can be shoveled to a higher level.

The general excavation is preferably carried only to the top of the footings or the bottom of the fill under the cellar floor because some

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soils become soft upon exposure to air or water and it is advisable not to make the final excavation for footings until it is nearly time to pour the concrete.

Deep excavations must be wide enough to provide space to work when constructing and waterproofing the wall. Where soils slide easily, it is sometimes more economical to make the excavation large enough so slides will not interfere with placing the walls than to install forms, cribbing, or other braces. Where farm slips, drags, etc., are used the extra earth can be moved economically. The general method of shoring up sliding banks illustrated in figure 26 may be adapted to special conditions.

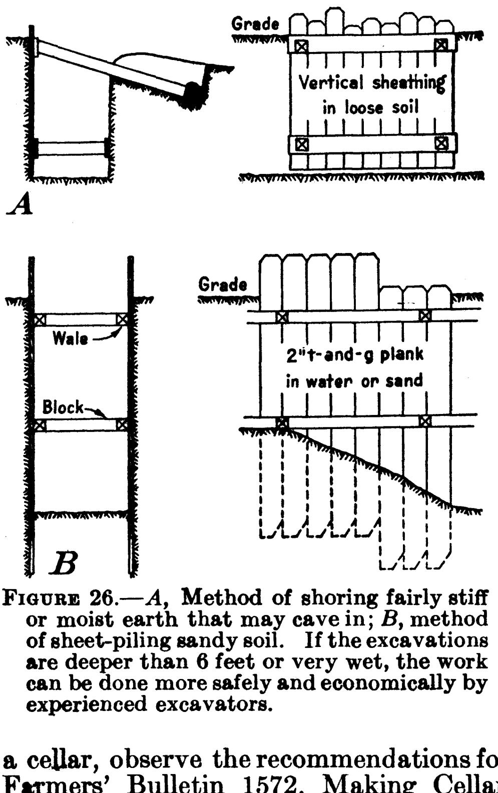

FIGURE 26.—*A*, Method of shoring fairly stiff or moist earth that may cave in; *B*, method of sheet-piling sandy soil. If the excavations are deeper than 6 feet or very wet, the work can be done more safely and economically by experienced excavators.

During the progress of the work keep the surface of the excavation sloped to a low spot where any water that may collect can be pumped out promptly and not saturate the whole area. Wet soil is difficult and costly to handle.

Concrete

Concrete is the most suitable material for footings, but often not enough attention is given to its proper making, placing, and curing or protection in freezing weather. Directions for making various classes of concrete for footings and walls and the method of building forms are given in Farmers' Bulletin 1772, Use of Concrete on the Farm. Where the wall is to enclose a cellar, observe the recommendations for proper construction given in Farmers' Bulletin 1572, Making Cellars Dry. In general a 1:3:5 concrete is suitable for footings and foundations; but where watertightness is essential, as for basement walls and floors, or where reinforcement is required use a 1:2½:3½ mix. In alkali regions special precautions are required to prevent deterioration of concrete; advice can be had from the State agricultural colleges.

The cement may be washed out of concrete if it is deposited in running water. If some unmuddied water is standing in the trenches and cannot be readily removed, use a dry and stiff mixture that will absorb the excess water.

When it is necessary to keep water out of an excavation by pumping, it may be economical to use early (quick-setting) high-strength cement instead of ordinary cement for that part of the wall below water level because the time of pumping will be shortened.

Sleeves for pipes, anchor bolts, blocking for windows, and other inserts in the wall can be located more accurately if placed securely in the forms before the concrete is poured. Cellar walls, especially in wet soil, are preferably poured as one unit to above grade. When the size of the job or equipment does not permit this, watertight joints between old and new concrete [9] are recommended.

Unit Masonry

Only strong, durable materials are suitable for use in a permanent foundation, especially in the part in contact with earth. Do not use clay brick and hollow tile unless sound and well-burned, nor concrete bricks or blocks unless of nonporous stone or gravel concrete. Cinder

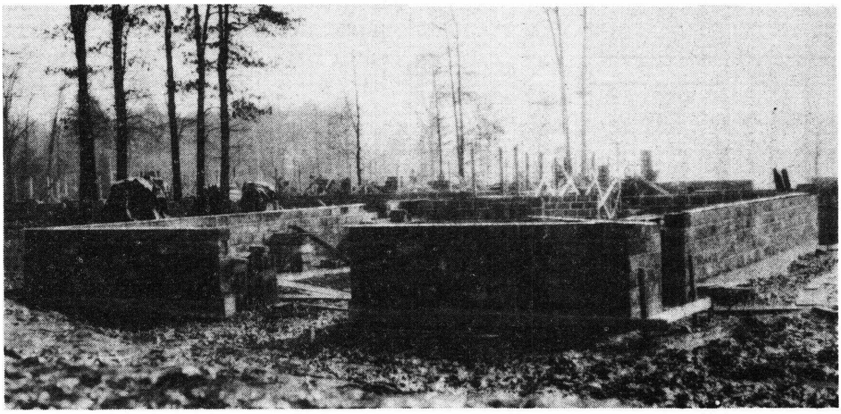

FIGURE 27.—Note the carefully placed batter boards, the pile of concrete block used inside for supporting the scaffold boards, and the boards on top of the wall, which hold down the paper strips that keep out rain.

blocks are not suitable for below-ground use when in contact with damp earth; however, certain lightweight concrete blocks made with manufactured aggregate are used successfully in some regions. Avoid the use of rock that is soft, porous, or subject to disintegration when exposed to the weather. Rock that is very irregular or that does not provide a good bearing surface does not make a strong foundation.

Brick, hollow tile, and other porous units will absorb more or less water from mortar, rendering it weak or useless unless the units are well wetted before using. This is done by spraying with water from a hose or dousing the stock pile until the water is absorbed—without a surplus on the surface. Hard-burned masonry units, if too wet, can be laid only with difficulty because of sliding on the mortar.

Masonry walls need to be covered and protected from rain and frost after the day's work and until the mortar has set. Boards or roofing paper, weighted down to prevent being blown away, are commonly used (fig. 27). Before the work is resumed, remove loose units and mortar and dampen the masonry. Masonry like concrete, must not be laid in freezing weather or when freezing may occur before the mortar has set.

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[9] U. S. Department of Agriculture Farmers' Bulletin 1772, Use of Concrete on the Farm, p. 27.

Scaffolds

As foundations generally are not high above the ground little or no scaffolding is needed. Generally piles of bricks or concrete block, 3 to 4 feet high, are placed 8 to 10 feet on center for supporting 2- by 12-inch boards (fig. 27). Masonry contractors keep a supply of frames 3 or 4 feet square for supporting the scaffold platform (fig. 28). The frames are stood on edge against the wall about 6 to 8 feet apart and temporarily braced with 1- by 6-inch boards crossed diagonally.

Mortar

The strength and watertightness of unit masonry depend to a great extent upon the kind of mortar and the quality of workmanship.

It is advisable to make all mortar used below grade of 1 part portland cement and 3 parts sand by volume; 5 pounds of hydrated lime per sack of cement makes the mortar more workable. Lime-cement mortar may be used above grade and is made with 1 part stiff lime-putty or dry hydrated lime, 1 part portland cement, and 6 parts sand, all measured by volume. Lime mortar consisting of 1 part stiff lime-putty or dry hydrated lime and 3 parts sand is often used for walls above ground that do not carry a heavy load.

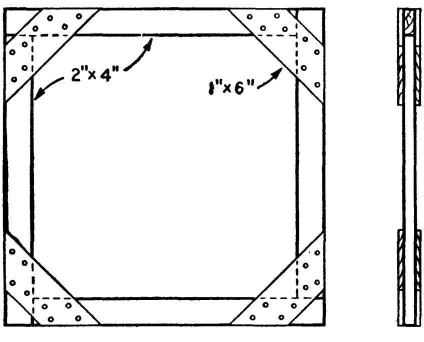

FIGURE 28.—Scaffold frames, or "horses," used in laying masonry walls.

Stiff lime putty which is used sometimes instead of dry hydrated lime is produced by slaking lump or pulverized quicklime or by mixing hydrated lime in water. Obtain directions for slaking quicklime at the time of purchase because all limes do not slake alike.

Sand for good mortar must be clean and sharp, and free from organic matter; the grains preferably averaging 1/16 inch in size and not larger than 1/8 inch—this is somewhat finer than concrete sand.

Mix mortar containing cement in batches that can be used within 30 minutes. Lime mortar may be mixed in larger batches. Partly set mortar must not be retempered but must be thrown away; wasting the mortar can be avoided by adding a little gravel before the mortar sets and using this concrete for filling hollow units.

It is best not to allow portland cement mortar to freeze. However, mortar is not injured by frost after the first set has taken place. Lime in mortar retards setting, and lime mortar must not be allowed to freeze. If the temperature is about 40° F. and liable to fall below 32° F. during the night, heating the masonry and mortar before they are placed, and protecting the finished work, are ordinarily sufficient. Heat mortar to between 70° and 100° and maintain the finished work at about 50° F. for 5 days by coverings of paper, boards, and straw. The method of heating sand described on page 25 of Farmers' Bulletin 1772, can be adapted to warming brick or other masonry units. Water for mixing the mortar must not be over 150° F. A practical test to determine the final set of mortar is to press with the thumb.

When the thumbnail fails to indent the surface the mortar may be considered to have reached its final set.

In making mortar the sand is first spread out on a mixing board or box and the dry cement or hydrated lime distributed evenly on top. When this mass has been thoroughly mixed with shovels and hoes, sufficient water is added and the mass remixed until a smooth plastic consistency is obtained.

The amount of mortar required for different kinds of masonry is given in table 3. It will be convenient to refer to the approximate field measurements given in table 6 when preparing putty for use in small batches of mortar.

TABLE 6.—*Field measurements of cement and lime*

Material	Commercial packages			Weight per cubic foot [1]	Quantity required per cubic foot of putty
	Unit	Volume	Weight		
		Cubic feet	*Pounds*	*Pounds*	*Pounds*
Portland cement	Sack	1.00	94	94	109
Hydrated lime	Bag	1.25	50	40	44
Quicklime	Barrel (3.5 bu.)	4.37	280	64	22.5
Do	Barrel (2.25 bu.)	2.81	180	64	22.5

[1] 1 Cubic foot=about 30 quarts; 4 quarts of hydrated lime weighs about 5 pounds.

Portland cement, mason's cement, and hydrated lime must be stored in a dry place and piled so that they will not touch the ground or side walls. Quicklime is a fire hazard if it is damp, especially when stored in large quantities in a combustible structure or with combustible materials.

Laying Brick

Bricklaying is started at corners. Twine lines are set across the batter boards in the marks indicating the face of the foundation and checked for trueness, because any deviation from trueness at this time will be a monument to carelessness and an annoyance as the work progresses. The corners (intersection of side and end lines) are projected to lower levels by means of a plumb bob or a mason's level. The corners are laid up to a convenient height (about 2 or 3 feet). Bricks are stepped up from the bottom row toward the corners to permit the proper bonding of the intermediate sections. After two corners have been built straight and plumb to the desired height, a twine line is fastened to line hooks or nails partly driven into a joint at one corner and stretched horizontally to the adjoining corner to mark the top and outer edge of the first course just above the footings. With the line as a guide, the bricks are laid in a full bed of mortar. To make certain that the bottom of the vertical joints will be filled, mortar is dabbed on the sides of the brick that will butt against the work in place. The brick is then worked into position by shoving so as to squeeze the mortar into the joints. The line is moved up as a guide for laying each course.

Corners are built up as needed and the above procedure repeated until the foundation is completed. When units are cut for placing anchor bolts, fill all voids with mortar.

The method of laying other kinds of masonry units is similar to that of brick. In general, the cells of hollow units are set vertical; however, hollow tile are often placed with the cells horizontal. When walls of hollow tile are built entirely with cells vertical and with webs carefully superposed, their strength is materially increased and may in some cases be 50 percent greater than when the tile are laid horizontally. As generally set, some or all of the vertical cross webs may not be vertically alined when set in the wall, and the effective bearing area of individual units may thus be reduced. This condition, together with the more uniform bedding of tile laid horizontally, offsets the difference in strength between individual units tested with cells horizontal and vertical. Therefore, no difference in bearing power is made between walls built with cells horizontal and those with cells vertical. For walls of hollow tile over 8 inches thick, it is advisable to use more than one unit, properly bonded to make up the thickness.

Bonds

Brick walls for ordinary work are laid in common bond, which means from 4 to 6 courses are laid with the long side of the brick parallel to the length of the wall and every fifth or sixth course a header course laid with the bricks crosswise. The vertical joints, three-eighths or one-half inch wide, are staggered at each course and bricks cut if necessary to avoid continuous vertical joints.

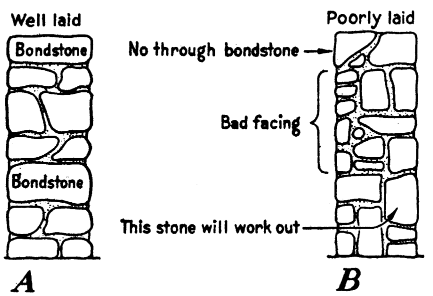

FIGURE 29.—*A*, Well-laid stone wall; note the bondstones extending through the wall; *B*, A poorly laid wall without bondstones is weak.

There are various other patterns, or bonds, used for laying brick which produce a wall more pleasing in appearance than the common bond, but generally such walls cannot be built without considerable experience.

Walls of stone can be made strong and reasonably watertight if care is used in selecting and laying the stone. Stones having flat tops and bottoms are preferable, and at least one bondstone is needed (fig. 29) for every 10 square feet of wall, extending clear through or into the wall at least three-fourths of the wall thickness. Lay stones with their flat surfaces horizontal and, if possible, so fitted to each other that there will not be large spaces between them. All joints must be completely filled; large spaces may be filled with small stone and mortar or with concrete. The larger stones are generally used in the lower part of the wall and at corners. The appearance of the wall is influenced by the shape and size of the rocks, and the pattern developed by arrangement of joints and differently colored stone.

Joints

Joints in masonry walls are usually finished in one of the three principal ways (fig. 30), rough, flush, or tooled, depending on the nature of the work. Rough joints are sometimes used in certain styles

of architecture but are of no benefit to the wall and are wasteful. A rough joint is produced simply by squeezing out excess material in the mortar bed. The flush joint is the most common in ordinary work and is made by scraping off with the trowel any mortar that squeezes out in laying and by filling any voids. Tooled joints *C* and *D* are more nearly watertight than the flush joint. The tooling is done before the mortar sets too hard, the trowel being used for the weathered joint and a short bend pipe or rod of a slightly larger diameter than the width of the joint for the rodded joint. The pipe or trowel is drawn along the joints with enough pressure to squeeze back the mortar and remove excess material, care being taken not to dislodge any masonry. The stripped joint, about one-half inch deep, provides a good mechanical bond for plaster or stucco and is easily formed when the masonry is being laid, by placing a ½-inch-wide stick in the joint, flush with the wall face, so as to keep mortar back from the face of the wall.

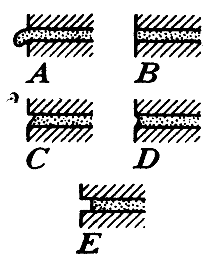

FIGURE 30.—Types of mortar joints. *A*, Rough; *B*, flush; *C*, weathered; *D*, rodded; *E*, stripped.

Waterproofing

It is a good practice to parget or stucco cellar walls of unit masonry with Portland cement mortar on the outside, at least below grade even though waterproofing is not needed. It will protect the walls and help to keep them dry under ordinary conditions by shedding rain. Walls that are rough, clean, and free of loose mortar and have joints raked out for a depth of one-fourth to one-half inch provide a mechanical bond for stucco. Apply stucco to the top of the footing that projects beyond the wall and bevel back to the wall stucco so as to seal the mortar joint between the footing and (the first course of masonry. A good stucco consists of a 1 to 3 cement mortar, plus 10 percent lime putty though it is sometimes made of 1 part cement, 1 part lime putty, and 6 parts sand.

A single coat is usually put on one-half inch thick, being forced into surface depressions to obtain a good bond and troweled on hard and tight. One cubic foot of stucco, if spread one-half inch thick, covers 20 to 24 square feet, depending upon the smoothness of the wall. In order to prevent too rapid drying of the stucco and to secure a good bond keep walls uniformly dampened, not soaked.

The stucco needs to be kept continuously damp for at least 2 days with only as much water as will be absorbed readily. Start moistening as soon as the stucco has hardened enough not to be injured by a fine spray from a hose; farm spraying equipment is practical to use. If this is not done the stucco will not be strong and may develop fine cracks, which may let water through. When possible, work on the shady side of the building during warm weather because the stucco will dry more slowly and is more easily applied.

When a true surface is wanted, stucco is put on in two coats, the scratch coat and the finish coat. Each coat is usually three-eighths inch thick. Before the scratch coat hardens, it is deeply cross-scratched with heavy wires or a rake to provide a key for the finish coat. After the scratch coat has been damp-cured for 2 days, it is allowed to dry thoroughly and then dampened just prior to the application of the finish coat. The second coat is also damp-cured for at least 2 days.

One cubic foot of stucco, three-eighths inch thick, covers 30 to 32 square feet.

Frequently the wall below grade is coated heavily with hot tar, which may or may not be protected with stucco. About 20 to 25 pounds of tar are needed for covering 100 square feet.

Backfilling

Do not backfill until the foundation has hardened sufficiently to stand the resulting pressure and the drain tile are installed and plastering or waterproofing completed.

The fill if well-tamped in 12- to 18-inch layers lessens shrinkage. When drain tile is used, gravel or cinders are preferably used for the lower layers and damp earth for the top; otherwise it is better to backfill with a clayey soil. Large frozen clods settle considerably when they thaw in the spring and had best not be used. It is desirable in backfilling around cellar walls to slope the layers down and away from the building to shed water better and cause less lateral pressure against the walls. Care is needed to avoid damage to the waterproofing when backfilling.

A fill intended to support a concrete floor requires thorough compacting. For large areas, rolling is more efficient than hand tamping. Where feasible the floor is made 6 to 8 inches higher than the outside grade with a fill of porous material such as gravel or cinders under the slab.

Mud holes are prevented if the surface of the ground under a building on piers is graded so as to shed water. Sandy-clay soil is an excellent material for the top 6 to 8 inches because, if graded to a suitable slope and packed hard while in a moist condition, a crust is formed which prevents water from reaching the footings and reduces the shifting of sandy soils by wind. One part Portland cement mixed thoroughly with 20 parts moist (not wet) clay-sand soil makes a durable crust if it is rammed hard.

REMODELING AND REPAIRS

The methods of securing firm foundations recommended throughout this bulletin suggest the appropriate remedy for many failures commonly occurring in farm structures. The repairer, before starting a project, ought to weigh carefully his ability to apply the corrective, under the definite conditions to be met and with such equipment as is available, so as not to endanger the superstructure or the workmen. It is also a consideration that the work be completed without delays which might result in damage from severe weather or other causes.

RAISING AND SUPPORTING BUILDINGS

Often major repairs and additions require that a structure be raised from its foundations and supported safely during the operations.

Frame buildings can be raised with screw jacks, wedges, or with long pole levers, depending upon their size and weight. Masonry structures are handled in the same general manner but involve special problems; therefore, attempts to raise them had best not be made except under the supervision of an experienced builder having adequate equipment.

When the nuts of anchor bolts cannot be removed, the shank of the

bolt can be sawed in two between the sill and the masonry or chiseled out if the masonry is not to be a part of the new foundation. All

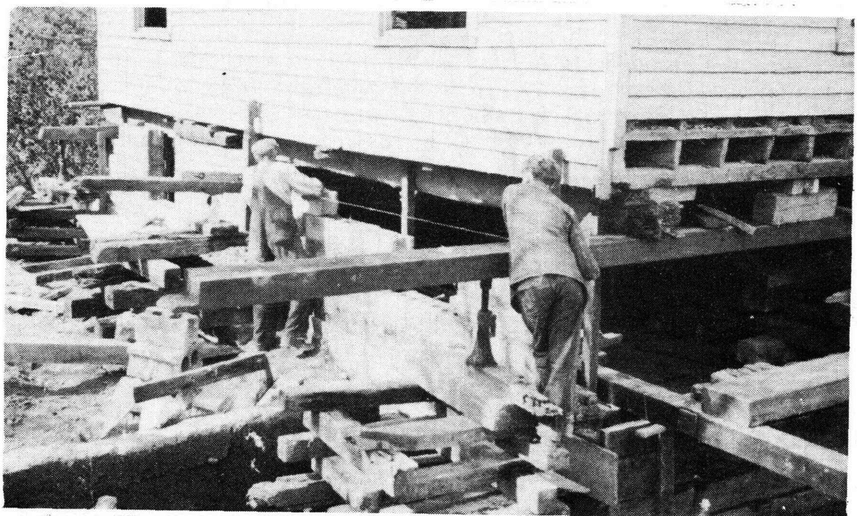

FIGURE 31.—Three needle beams, or temporary sills, were used to support this house; four jacks and sets of blocking were used under each.

electric and telephone wires, water, steam, sewer, and other pipes, masonry steps, etc. must be disconnected.

Temporary sills, or needles (fig. 31) of 8- by 8-inch or 12- by 12-inch timber are needed for the building to rest upon so as to prevent sagging

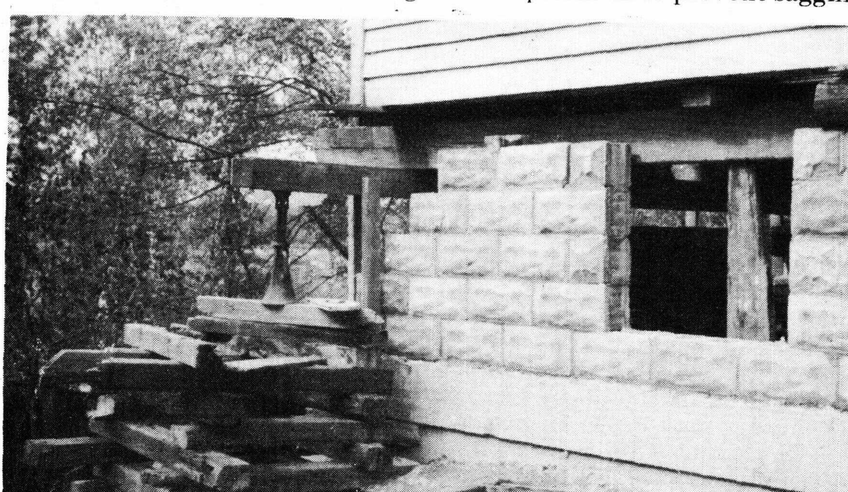

FIGURE 32.—The temporary sill extends the proper distance from the wall to allow room for locating jack and blocking.

of walls and floors. They are usually placed as near the original supports as practicable and extend beyond the walls of the building far enough to allow room for operating the jacks, which press directly on their bottoms (fig. 32).

Cribbing or blocking is used to support the temporary sills (fig. 33) and is so located as not to interfere with the construction of the wall. The blocks must also be spaced close enough together to prevent the temporary sills from bending while supporting the weight of the structure. The blocking is best set on firm, dry ground that will not become soft after a rain, and must be carefully built up so as not to rock or tip. Sometimes 2-inch plank are laid close together on the ground as a footing to distribute the load from the blocking. Never

FIGURE 33.—The blocking shown is 12 inches from the wall. Where the soil is sandy or the wall excavation deep, the blocking must be farther from the building to avoid cave-ins. The two blocks under the foot of this jack, as shown, are dangerous as they may tip.

place a jack where it might slip or tip when loaded. Remove from the structure feed, machinery, hay, and other heavy loads, or property that might be damaged, before starting to raise it. Large structures without cross partitions require stiff diagonal braces inside to prevent collapse, and long struts or guy wires outside to resist wind pressure while the work is in progress.

Ordinarily a sufficient number of jacks are not available to raise the whole building at one time. In this case, it is best to raise one side a little, set blocking to hold it in place, and progress around the building by stages until the desired height is reached. Jolts and too great movements may cause an accident. It is important to prevent the jack gear from slipping or jamming. Replace the jacks as soon as possible with blocking and wedges or pole braces, and never leave them carrying the load over night or for long periods because vibration or wind may cause them to slip.

Figures 31 to 34 show the general methods of using beams, cribbing, and jacks for raising and supporting buildings. These methods can be adapted to special problems.

PLACING MASONRY WALLS IN SECTIONS

Masonry walls of large buildings are more safely and easily rebuilt if alternate sections 4 feet long and 8 feet apart are replaced at a time. A hole is first made through the wall to permit slipping the temporary sill, or needle beam, under the house sills (figs. 31–34). After the weight of the building has been transferred to the needle beams by jacks and then blocking substituted for the jacks, a short section of the wall can be torn out and the excavation made to the bottom of the footing. When only a small portion of the building is raised, post supports are often sufficient and offer less obstruction than beams

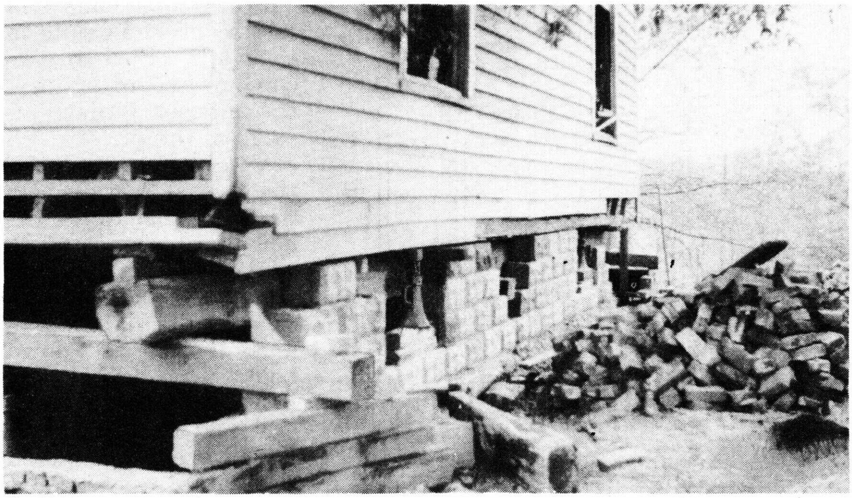

FIGURE 34.—Sections of the wall were built around the temporary sills, or needle beams, which were located where the masonry is omitted. The space can be filled in without cutting the concrete block.

and blocking. While a concrete footing is advisable, the wall proper can be built more conveniently if of unit masonry.

Care must be taken to make the tops of footings level and, if necessary on account of ground slope, to step them (see fig. 4) so that the difference in the elevations of the steps is a multiple of the height of a masonry unit plus the thickness of a mortar joint. If this precaution is taken, the various courses will be at the same elevation, and the horizontal mortar joints will be continuous. When concrete blocks are used, it is advisable to lay out the first course for the entire length of the wall so that the first block in each section may be properly located. By doing this, blocks between the various sections (fig. 34) can be fitted in and toothed together properly.

ADDING CELLARS

Usually when a cellar is to be built under the whole house the work had better be done in sections as it may be costly and hazardous to excavate the whole cellar at one time. The general methods of raising and supporting a building and of constructing walls in sections can be used.

Unless a building is of sound construction and in good condition it is poor economy to build a large cellar. However, sufficient space for a heating plant can be provided without great cost or labor, if the chimney is accessible, by locating a cellar 8 to 10 feet wide near one outside wall. The farther the cellar is under the house the greater the amount of work involved. One or more rows of piers are generally used to support interior girders. An opportunity is thus afforded for digging trenches midway between rows of piers and for building the walls without the need of elaborate temporary braces. If headroom permits make the side walls (fig. 35, *ae*, and *bf*) parallel to the girders because it is relatively easy to span a cellar only 8 to 14 feet wide with steel I beams or heavy wood girders (*cd*) so that their ends will rest securely in slots in the walls. Such girders can be used to support the interior girders instead of the piers which are to be removed. If the two side walls are perpendicular to the girders, steel beams can be slipped directly under the house girders. An existing foundation wall must be carried down below the cellar floor, as described on page 35.

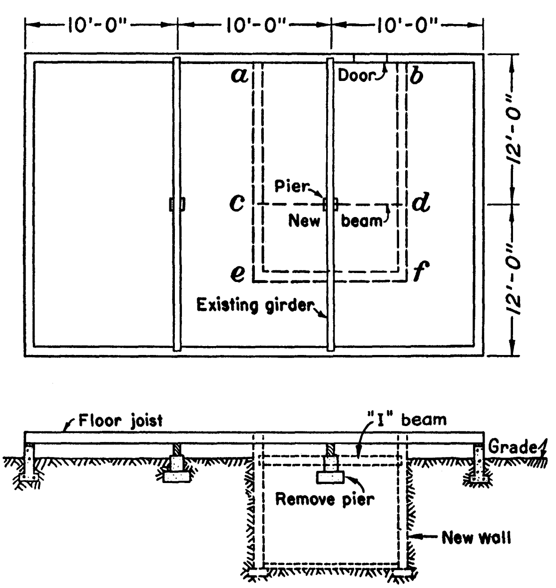

FIGURE 35.—In locating a small cellar care must be taken not to let sliding sandy soil undermine nearby piers or walls.

After these operations have been completed the earth in the cellar between the new walls can be removed through an opening which may later be used for a door in the outside wall. The rear wall of the cellar can be built after the excavation has been completed. When the foundation is entirely of piers, four masonry walls are needed.

When work is being done under a house there is none too much room at best, and piles of earth are very inconvenient. Metal drag slips are convenient for excavating or removing earth from the cellar and can be drawn from under the house with a team and chain. Where a slip is not available, a slide (fig. 36) will prove handy if dirt from the trenches is piled upon it instead of on the ground.

If a wheelbarrow is used the heavy labor in wheeling up a slope may be lightened by having a hooked rod or rope pulled by one or two men outside.

When a house has tight, continuous foundation walls the walls of a part-cellar, such as those described above are sometimes built only as high as the earth grade under the building so as to allow heat to circulate under the first floor.

Masonry piers or wooden posts can be provided on top of the new walls to support the ends of the beams, which must be located so as to carry the weight on the house girders when the original piers are removed.

Extending Chimney, Piers, and Walls to a Lower Level

When a chimney is within the area of a cellar it must be supported on two or three heavy timbers or, preferably, on steel beams. The ends of these beams must be supported on blocking (as described previously) located so as to permit excavating and building the necessary masonry which extends below the cellar floor. The exact method of placing the timbers and blocking depends upon local conditions. Ordinarily holes are cut in the masonry just above the footing for inserting the supporting timbers, and the old footing is cut off. After the new masonry extension is strong enough to support the weight, the timbers are withdrawn and the holes filled in with masonry.

When the cellar is to be used for storage only, expense can be saved by locating the excavation so that the chimney will not have to be carried down to a lower level. When piers are to be extended to a lower level it is ordinarily more economical to support the girders on blocking, tear out the old piers, and build new ones, starting from the footing below the cellar floor. Pipe, structural steel, or wooden columns can be used under such conditions more expeditiously than masonry.

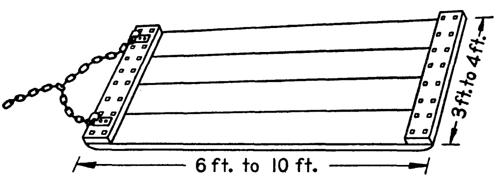

FIGURE 36.—If the chain of the slide extends beyond the building it can be fastened to a truck or team outside. If the slide is dragged at a sharp angle over the mound, the earth can be spilled instead of having to be shoveled off.

When unit masonry is used for extending walls to a lower level, the top tier of blocks immediately under the old footing may have to be omitted and the space filled with stiff concrete because of the unevenness of the bottom of the concrete footing. Ordinarily too much labor is required to chisel off the projections or variations from a true level to permit fitting the last tier of blocks in place; however, all adhering earth must be removed to secure a good bond. A boxlike form can be used to keep the concrete in place. The weight of the walls or beams may be supported in the manner described on page 7.

Figure 37 suggests a convenient arrangement of forms where the extension is to be of poured concrete. The projection of the footing may be chiseled off plumb with the wall or only small sections, 12 to 18 inches long, chiseled out to facilitate placing the last few inches of concrete.

While it is feasible to build a retaining wall within the area of a proposed cellar rather than to excavate and extend the masonry down directly under the foundation, this is not good practice except under special supervision. Unless such a wall is so placed that it is not subject to pressure from the old wall, it must be built strong enough to resist the pressure or be reinforced. The safe distance that must be allowed between the two walls to avoid lateral pressure depends upon

the angle of repose of the earth and the vertical height between the old and new footings. In loose, sandy soils do not put the new cellar wall closer to any foundation than 1.5 feet for each vertical foot between the two footings. If the new footing is 4 feet lower than the old footing, 6 feet must be allowed between the walls. The horizontal distance to be allowed for each vertical foot varies for different soils, as follows: Damp plastic clay, 2 feet; various mixtures of sand, dry clay, gravel and ordinary soil, 1½ feet; rotten rock, cinders, ashes, 1 foot. If the soil becomes very wet, greater distances must be used. Where such a condition is likely, special consideration is required.

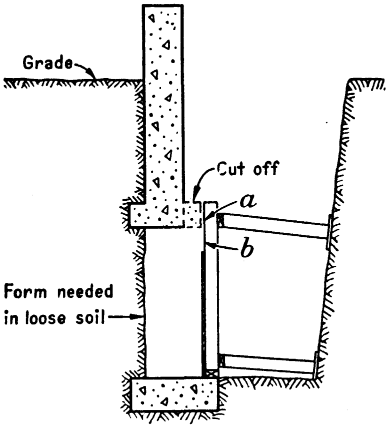

FIGURE 37.—The top boards of the form at *b* are omitted until the concrete reaches the top of the highest board in place; they are then slipped in behind the studs and the balance of the concrete poured, as a soft mortar if necessary through the openings, *a*, provided in the old footing.

REPAIRING DEFECTS

Foundations that have settled indicate they are not deep enough to withstand erosion or frost action, or that the piers or walls have too little bearing area for the type of soil and the load carried. Settlement may also be due to rotted wood posts and sills or defective masonry.

The building can be jacked up level and supported while the foundations are being repaired or replaced by one of the methods described. A good method of increasing the width of a footing is shown in figure 38.

Where a wall has been slightly undermined (fig. 2) and the masonry is not damaged, it is often feasible to ram damp (not wet) sandy clay earth under the footing so as to secure a firm bearing; 5 to 8 percent portland cement, by volume, mixed with the earth will produce a harder and more enduring packing. Earth is then banked against the wall high enough for frost protection (fig. 3) and the surface sloped to divert surface and roof drainage. Heavy sod or shrubbery afford protection from wind erosion.

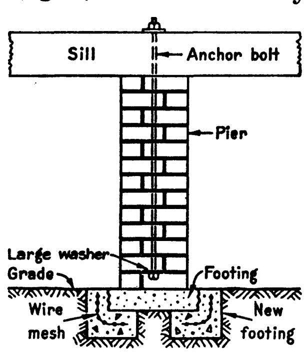

FIGURE 38.—A method of increasing the width of a footing. The load on the pier must be relieved until the new footing has hardened.

It is frequently more economical to relieve overloaded foundations by installing extra piers than to increase the width of existing footings. Care must be taken to make sills and girders actually rest on new and old work. New footings may settle a little when the superstructure is lowered onto the piers so that shims or wedges of durable material like slate or flat pieces of hard tile must be used to secure a tight fit and a level girder. Occasionally a pier is made about one-half inch higher than its final grade to allow for settlement. A small

additional load on an old foundation above that originally intended generally is permissible because the earth under the footing becomes denser and more solid after having supported a load for some time.

Piers or foundations which lean (fig. 39) are difficult to plumb or push into place. Ordinarily it is more economical to jack the building up level and rebuild the foundation so that it will support the structure properly.

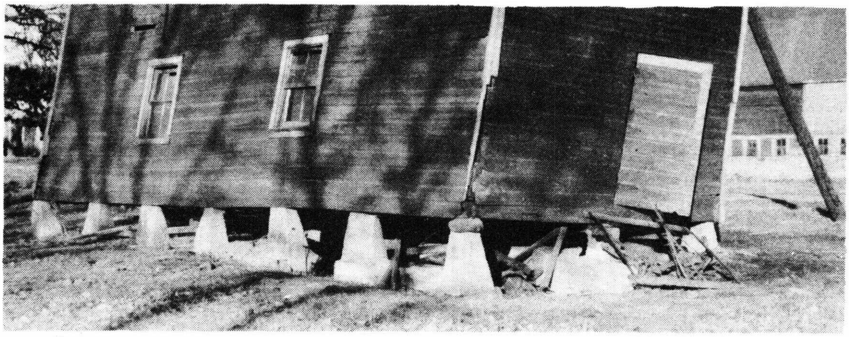

FIGURE 39.—A common type of failure of pier construction. These piers were not heavy enough to resist wind against so tall and narrow a structure and were pushed in various directions.

Deterioration of exposed wood usually begins at joints and causes metal fasteners to loosen. If loose spikes and driftbolts are removed, the holes and affected areas can be treated with a preservative and plugged up with wooden dowels or tar. Replace the spikes or bolts in new locations. Sections of unsound sills can be cut away and

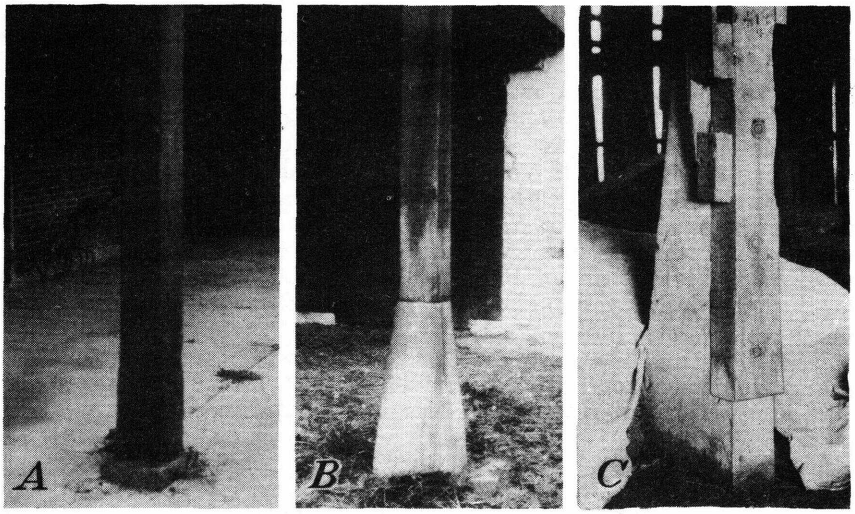

FIGURE 40.—*A*, Wood post rotten at ground level; *B*, concrete pier replacing rotten lower end of wood post; *C*, precast stub post, 8 by 8 inches at the top, 8 by 18 inches at the bottom, and 8 feet long, reinforced with six ⅞-inch twisted rods and bolted to the wood post with three ⅝-inch bolts.

repaired with plank patches unless the timbers have been weakened, in which case a new sill must be provided.

Untreated wooden posts rot rapidly at the ground line (fig. 40, *A*) and are best replaced with durable or treated posts or masonry piers (fig. 40, *B*). Figure 40, *C*, illustrates an effective method of repairing the lower end of a post with precast concrete.

MOVING BUILDINGS

When it is necessary to move a building to another site, unless it is a very simple structure, a specialist had better be engaged to do the work because of the hazard and the large amount of heavy equipment generally involved. The foundation usually is not built until after the building has been moved to its new site and jacked up on cribbing so the first floor is at the desired height and the building plumb. A foundation built prior to moving the building may be damaged or may not fit the structure unless the specialist has the proper equipment, since the building may be altered in shape or the opposite walls may not be exactly parallel or of equal length. There is less risk of damage to the structure if the foundation is placed in sections, as previously discussed, p. 33. If the excavation for the whole basement is made at one time the banks might cave in and cause the temporary cribbing to slide or settle.

DESIGNING FOUNDATIONS

LOADS

There are two types of loads on a foundation, "dead" load and "live" load. The dead load is the weight of the building itself (roof, floors, partitions, walls, foundation) and is always present. The live load consists of people, animals, furniture, snow, wind, grain, fruit, etc., and varies in amount, depending upon the weather and the quantity of the removable materials in the structure at various times. Only one-half the full live load of a farmhouse need be used in designing foundations as it would be exceptional for all the floors to be fully loaded at the same time. The full live load is used for determining the size of girders and beams because the full load might be concentrated on any one. Full live loads are used in the design of footings for storages and buildings for public assembly. In many localities buildings for public gatherings must meet the load requirements of the local building code.

The following dead loads and live loads will simplify estimating foundation loads for farm structures. Tables 7 and 8, respectively, will be useful in determining the area of wall and pier footings.

Dead Loads

	Pounds per square foot
Roofs:[1]	
Ordinary gable roofs (including sheathing, wood shingles)[2]	6
Gable roofs, 34 feet + 0, 36 foot span with self-supporting trusses 2 feet apart (includes sheathing, wood shingles)[2]	9
Braced rafter barn roof (includes slats, wood shingles)[2]	13
Gothic, sawed rafters (includes sheathing, wood shingles)[2]	12
Asbestos shingles (additional weight)	3
Built-up tar and gravel roofing (additional weight)	4.5
Slate, ⅛ to ¼ inch thick (additional weight)	4.5 to 6.5

[1] Pounds per square foot horizontal projected roof area.

[2] 2 pounds included for wood shingles; roll roofing, tin, and corrugated metal about same weight.

Dead Loads—Continued

	Pounds per square feet
Framing:	
Lumber in general (per foot, board measure)[3]	2. 5
2- by 12-inch joists, 2 feet apart	2. 6
2- by 10-inch joists, 16 inches apart	3. 1
2- by 8-inch joists, 2 feet apart	1. 7
Sheathing, flooring, or drop siding	2. 5
Plaster on wood lath	6 to 8
Plaster on metal lath	10
2- by 4-inch studs, 16 inches apart (includes plates and sills)	2. 0
2- by 4-inch studs, 2 feet apart (includes plates and sills)	1. 5
2- by 6-inch studs, 2 feet apart (includes plates and sills)	2. 3
Cement stucco	10
Stud partition, plaster both sides	16
Masonry:	
Cinder-block wall, pounds per inch of thickness	6
Concrete-block wall, pounds per inch of thickness	8
Brick wall, pounds per inch of thickness	10. 5
Rubble-stone, solid-concrete wall, pounds per inch of thickness	12. 5
Clay-tile wall, pounds per inch of thickness	4. 5

Live Loads

First floor in dwellings	40
Second floor in dwellings	30
Attic floor in dwellings	20
Roofs, in general	20 to 40
Assembly halls (where crowds collect)	100

	Pounds per cubic foot
Weight of produce:	
Apples, carrots	40
Beans, beets, potatoes, wheat, shelled corn [4]	48
Ear corn, husked [5]	28
Oats [4]	26
Bran	16
Loose hay	4 to 5
Chopped hay	10 to 13
Ordinary baled hay	10 to 13
Baled straw	6
Lime, fertilizer	55 to 60

[3] 1 board foot (1 foot b. m.) of lumber is equal to 1 square foot 1 inch thick. For estimating the weight of lumber of various dimensions, calculate the feet b. m. (multiply the width by the thickness in inches and by length in feet and divide by 12).
[4] Small grains occupy about 1¼ cubic feet per bushel.
[5] Ear corn cleanly husked occupies about 2½ cubic feet per bushel.

TABLE 7.—*Safe total load, per linear foot, on wall footings*

Width of footing (inches)	Bearing area	Soil bearing value in pounds [1]					
		1,000	2,000	3,000	4,000	6,000	8,000
	Square feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
8	0. 66	670	1, 340	2, 000	2, 670	4, 000	5, 340
10	. 83	835	1, 665	2, 500	3, 335	5, 000	6, 665
12	1. 00	1, 000	2, 000	3, 000	4, 000	6, 000	8, 000
14	1. 16	1, 165	2, 335	3, 500	4, 665	7, 000	9, 335
16	1. 33	1, 330	2, 670	4, 000	5, 330	8, 000	10, 670
18	1. 5	1, 500	3, 000	4, 500	6, 000	9, 000	12, 000
20	1. 67	1, 670	3, 335	5, 000	6, 670	10, 000	13, 340
22	1. 83	1, 835	3, 665	5, 500	7, 335	11, 000	14, 665
24	2. 0	2, 000	4, 000	6, 000	8, 000	12, 000	16, 000

[1] See page 3 for bearing values of different soils.

Table 8.—*Safe total load on square pier footings*

Size of footing (inches)	Bearing area	Soil bearing value in pounds per square foot [1]					
		1,000	2,000	3,000	4,000	6,000	8,000
	Square feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
12	1.0	1,000	2,000	3,000	4,000	6,000	8,000
14	1.36	1,360	2,720	4,080	5,440	8,160	10,880
16	1.77	1,780	3,560	5,340	7,120	10,680	14,240
18	2.25	2,250	4,500	6,750	9,000	13,500	18,000
20	2, 78	2,780	5,560	8,340	11,120	16,680	22,240
22	3.37	3,370	6,740	10,110	13,480	20,220	26,960
24	4.00	4,000	8,000	12,000	16,000	24,000	32,000
27	5.06	5,060	10,120	15,180	20,250	30,370	40,500
30	6.25	6,250	12,500	18,750	25,000	37,500	----------
33	7.55	7,560	15,120	22,680	30,240	45,360	----------
36	9.00	9,000	18,000	27,000	36,000	----------	----------
39	10.56	10,560	21,120	31,680	42,240	----------	----------
42	12.25	12,250	24,500	36,750	----------	----------	----------

[1] See page 3.

Calculate the weight on piers and walls for the various methods of applying loads so that post or pier footings will not be made too small in proportion to the wall footings. In general, the load carried by a pier is the weight on the adjacent half of beams or girders supported by the pier or wall.

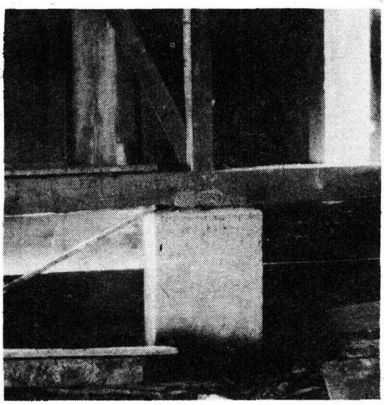

Figure 41.—Well-reinforced footings bear up the concentrated loads of this post and girt frame barn. They are of good strong concrete and withstood a hurricane that wrecked adjacent barns.

Frequently post and girt construction is employed for farm buildings, and continuous foundations are used under the outside walls. This type of construction ought not to be confused with the ordinary stud-wall type, in which the weight of the floors, roofs, etc., is uniformly distributed. The foundations under the posts along the side walls may be designed as individual piers, or the wall and footing may be widened (fig. 41) because the posts carry concentrated loads from cross girders; the foundation wall between the posts is a curtain wall and carries practically no weight. However, it must be bonded to the piers to prevent tipping and to anchor the building against winds.

Examples

Two general examples, a house and a barn, are given to show the application of the above data in estimating suitable-sized footings.

Example 1

Estimate the size of footings required for the two-story farmhouse shown in figure 42.

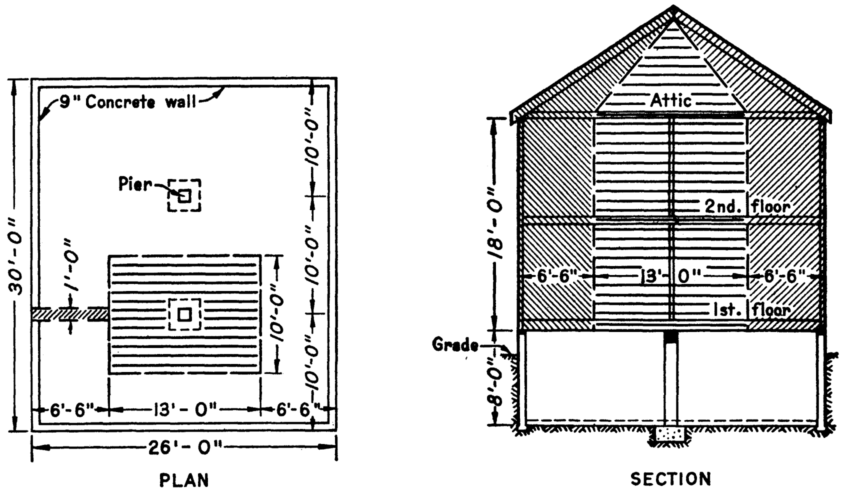

FIGURE 42.—Dotted lines mark midpoint of spans. The areas indicated by horizontal lines carry loads to a pier, and the areas indicated by diagonal hatching carry loads to a 1-foot length of wall.

WALL LOADS.—Dead load per linear foot on soil under wall, see page 38.

	Pounds	*Pounds*
Roof framing	6	
Asbestos shingles	3	
	9 × 13	= 117
Attic joists	1. 7	
Attic plaster	7. 0	
	8. 7 × 6. 5	= 57
Second-floor joists	2. 6	
Single flooring	2. 5	
Plaster	7. 0	
	12. 1 × 6.5	= 79
First-floor joists	2. 6	
Double flooring	5. 0	
	7. 6 × 6.5	= 49
Wall studs, 16 inches apart	2. 0 × 18	= 36
Double sheathing	5. 0 × 18	= 90
Plaster	7. 0 × 18	= 126
Concrete wall, 9 inches thick	12. 5 × 9 × 8	= 900
Total dead load		1, 454

Live load per linear foot on soil under wall, see page 39.

		Pounds
Roof	30 × 13 =	390
Attic	20 × 6.5 =	130
Second floor	30 × 6.5 =	195
First floor	40 × 6.5 =	260
Total live load		975

The total load on the soil may be taken as the total dead load plus one-half the live load, 1,454+488 or 1,942 pounds per linear foot of wall.

PIER LOADS.—Dead load on one pier, 12- by 12-inch (1 square foot, area).

		Pounds
Attic	8.7×13×10=	1,131
Second floor	12.1×13×10=	1,573
First floor	7.6×13×10=	988
Plastered partition	16×10×18=	2,880
Brick pier	10.5×12× 8=	1,008
Total dead load		7,580

Live load on one pier, see page 39 (use total dead and half-live loads).

Attic, 20; second floor, 30; first floor, 40; 90×13×10=11,700 pounds.
Total load on one pier: 7,580+5,850=13,430 pounds.

A brick pier higher than 10 times its smaller side is not recommended. The pier is 96 inches high and is safe, since the height limit, 120 inches, is not exceeded.

The brickwork carries 13,430 pounds on an area of 144 square

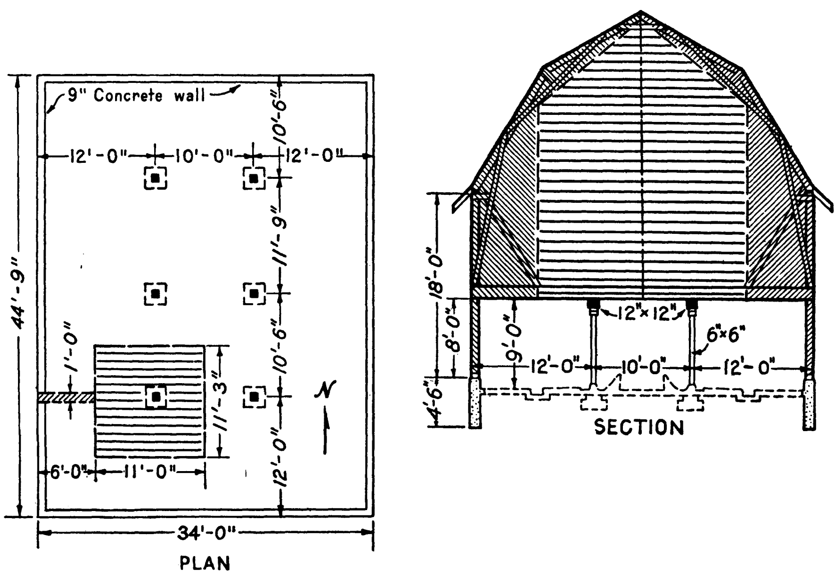

FIGURE 43.—The areas shown in horizontal lines carry load to columns and those indicated by diagonal lines carry loads to a 1-foot length of wall.

inches, which equals 93 pounds per square inch, and this is not in excess of the 130-pound per square-inch limit of table 6.

Notice the great difference between the soil load under the wall and under the pier. The 1,942 pounds on the 9-inch wall equals 2,588 pounds per square foot. The pressure on the pier is 13,430 pounds per square foot. To prevent unequal settlement, a large

footing is needed under the pier so that its pressure on the soil may be equal to that of the wall.

SIZE OF FOOTINGS.—It is assumed that the foundation bed is of ordinary clay with a bearing value (page 39) of 3,000 pounds per square foot.

Wall footing.—From table 7 it will be seen that for a soil bearing value of 3,000 pounds, a footing 8 inches wide will be needed to distribute the 1,942 pounds. The foundation wall could be made 8 inches thick instead of 9 if of good concrete and if footing is not needed.

Pier footing.—From table 8 it will be seen that under the same soil conditions a footing 27 inches square will be needed to distribute the 13,430 pounds. As a check, the footing weighs 760 pounds; this added to the 13,430 pounds=14,190 pounds, which is a safe load.

As the pier is 12 inches square the footing will project 7.5 inches beyond each side; and, according to the rule on page 8, it must be at least 11.2 inches thick. Twelve inches would be a practical thickness.

Example 2

Estimate the size of footings required for the wall and piers of the barn shown in figure 43 when mow is full of loose hay.

WALL LOADS.—Dead load per linear foot on soil under wall, see page 83.

		Pounds	Pounds
Braced rafter roof		13 × 17=	221
Mow joists	2.6		
Single floor	2.5		
Wood ceiling	2.5		
	7.6	× 6 =	45.6
Wall studs	2.3		
Double sheathing	5.0		
	7.3	× 18 =	131.4
Wall (inside finish)	2.5	× 8 =	20
Concrete wall	12.5	×9×4.5=	506
Total dead load			924

Live load per linear foot on soil under wall, see page 39.

Hay is piled 19 feet high 6 feet from wall and 9 feet high at the wall=14 feet average height.

	Pounds
Hay load= 5×14×6=	420
Roof =30×17 =	510
	930

The total load on the soil=924+930=1,854; 1,900 pounds per linear foot.

PIER LOADS.—The columns are spaced from 10 feet 6 inches to 12 feet apart. The longest girders rest on the first column from the south end. The heaviest load is at this point, and the footings must be large enough for safety. The small variation of loads on the second and third columns is negligible for practical purposes.

Dead load on pier:	Pounds	Pounds
Mow joists	2.6	
Single floor	2.5	
Ceiling	2.5	
	7.6×11×11.25=	940
Girder	2.5× 8×11.25=	225
Post	2.5× 3× 8 =	62
Footing	12.5× 4×14 =	700
Total dead load		1,927

Live load on pier:

Hay is piled 19 feet high 6 feet from wall, and 22 feet high in center of barn=20.5 feet average height.

Hay load 5×20.5×11×11.25=12,682 pounds.
The total load on the soil=1.927+12,682=14,609 pounds.
Assumed total load, 15,000 pounds.

SIZE OF FOOTINGS.—It is assumed the foundation bed is of ordinary clay with a bearing value (page 39) of 3,000 pounds per square foot.

Wall footing.—From table 7 it will be seen that for a soil bearing value of 3,000, a footing 8 inches wide will be needed to distribute the 1,900 pounds. The foundation wall could be made 8 inches thick instead of 9 inches if of good concrete. No footing is required unless brick or other unit masonry is used for the wall.

Pier footing.—From table 8 it will be seen that under the same soil conditions a footing 27 inches square will be needed to distribute the 15,000 pounds. The 24-inch square footing assumed is too small and must be made 27 inches so as to create the same unit pressure on the soil as does the wall footing.

A concrete base 9 inches square is used to raise the end of the wood post off the floor and protect it from moisture; therefore, the 27-inch footing will project 9 inches beyond the pier, requiring a thickness of 13.5 inches. (See page 8.)

It might be well to investigate the effect on the pier footing of filling the mow with chopped instead of uncut hay.

Loose hay weighs 5 pounds per cubic foot and chopped hay 13 pounds, or two and six-tenths times as much. The live load from chopped hay would be 32,979 pounds as compared with the 12,682 pounds from loose hay.

The total load on the footing would be 32,979+1,927=34,906 pounds.

From table 8 it is evident that a 42-inch-square footing is needed. Thus, in this barn, designed for loose hay, chopped or baled hay must not be stored to a depth greater than 8 feet. Otherwise beams, girders, and footings would be overloaded.

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